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Developing and Validating a New Product for Gripping and Pulling Cable

An Integrated Project
Submitted to the Faculty of



Department of Engineering Management

Compiled by
Tyler Miller

In Partial Fulfillment of the Requirements for the Degree of
Master of Science in Engineering Management

January 2018

Committee Members

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	Name	Signature
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Third Reader:	<u>Dr. Zachariah Chambers</u>	_____

Abstract

During on-site visits, it was discovered that the process of setting up cable for installation in conduit takes approximately 15 man-minutes of labor, costing contractors approximately \$300 a day in labor costs. This integrated project examined the validity of a new product which would save labor costs by decreasing the preparation time for installing cable in conduit.

Marketing strategies were examined as well as business models. The design of the product consisted of 3D modeling, rapidly-manufactured prototypes, design space selection, testing, and refinement.

In time trials, the final product cut preparation time from 15 minutes to 1 minute, saving contractors approximately \$280 each day on a job. Lab tests showed a maximum recommended tension of approximately 200lb, depending on the cable being pulled. The product is able to hold cable bundles with diameters up to 1.5".

Customers who were presented with the design looked forward to a finished product, stating that they would pay approximately \$300 retail price for the solution.

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List of Abbreviations

BMC – Business Model Canvas

DOE – Design of Experiments

HSS – High Speed Steel

RFQ – Request for Quote

List of Variables

Variable	Description	Units
A	Tooth Pitch	Threads Per Inch
B	Internal Taper	Degrees
C	Tooth Backwards Tilt	Degrees
D	Internal Diameter of Conduit	Inches
D_b	Diameter of Pulling Grip's Internal Bore	Inches
F	Factor of Safety	Unitless
H	Distance from Origin of Pipe Bend to the Center of Chord Created by Pulling Grip	Inches
L	Exterior Length of Pulling Grip	Inches
L_t	Approximate Length of Pulling Grip's Effective Internal Threads	Inches
L_x	Length of the Pulling Grip Which Does Not Comprise Length of Effective Threads	Inches
R_c	Radius to Center of Conduit	Inches
R_i	Radius to Inside Internal Edge of Conduit	Inches
R_o	Radius to Outside Internal Edge of Conduit	Inches
R_t	Perpendicular to Central Axis of Pulling Grip, the Span of Internal Threads	Inches
T_w	Thickness at the Narrowest Walls of the Pulling Grip	Inches
W	External Diameter, or Width, of Pulling Grip	Inches

Introduction

This integrated project was conducted to determine the viability of a business venture which pursues the manufacture and sale of a new product to pull cable through conduit. The viability of the business venture was evaluated based on the market's need for a solution, the design of a product based on customer needs, customer feedback, and the potential revenues associated with the design.

The problem was first identified through an on-site visit with Sycamore Engineering, where it was examined that the current method of attaching cable bundles to fishing tape was dangerous, tedious, and inefficient. It was hypothesized that the current process of pulling cable could be made more efficient through the introduction of a specialized tool.

The tool is known in the industry as a pulling grip. It establishes a connection between the bundle of cables to be installed and the fish tape, which is what pulls the cable through the conduit (see Figure 1). The proposed solution is distinctly different from any competitor's solution. The proposed solution features an internal, tapered thread to make connection with a cable bundle via twisting the grip onto the bundle.

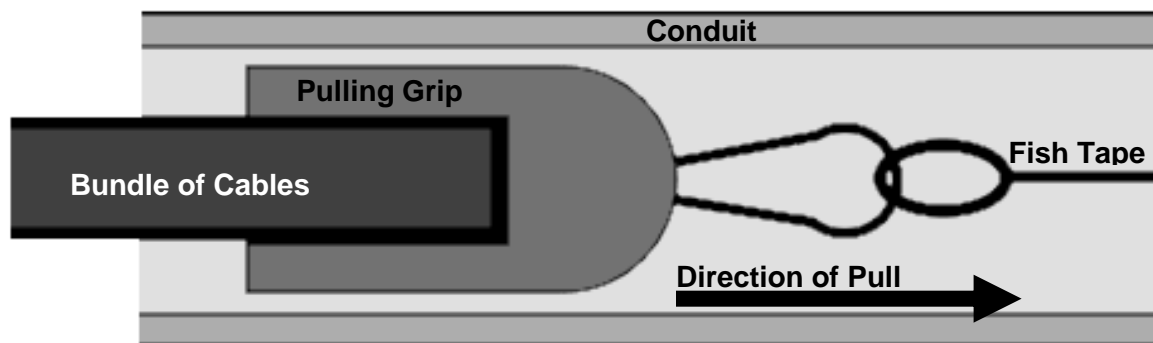


Figure 1: Pulling Grip Assembly Inside Conduit

Market research was conducted to demonstrate the current position of competitors in the market space, as well as the viability of creating a business venture based on the product. Competitors such as Greenlee and Southwire were examined, their solutions identified and compared against the proposed design. Research was also conducted to determine the need for the proposed solution in the market, as well as the potential number of customers and profitability of the solution.

Then, an intellectual property search was conducted to determine if the proposed design was similar to any existing patents. Patent grants and patent applications were both examined.

A marketing strategy was crafted for how the potential solution would be introduced to the market in a way that would most efficiently demonstrate value and increase demand. This strategy involved the use of public conferences, trade magazines, and other publicized events.

A business model was also created to determine economic feasibility of the venture. Value Proposition, Customer Segments, Key Partners and Resources, Cost/Revenue models, and other information were documented in a Business Model Canvas (BMC). This BMC summarized much of the data previously mentioned, and organized it into a readily legible document.

Customers and purchasers of the product were solicited for product requirements. This led to the determination of an initial product specification, including the required holding strength and the required compatible span of cable bundle diameters. Other needs were also determined, such as the product must be usable by a customer wearing gloves, and that the design should be easily reassembled.

Prototypes were created to preliminarily test aspects of the proposed design. Design spaces were then created to determine the exterior geometry of the design, while a Design of Experiments was used to determine the interior geometry. The proposed design was altered according to the results to optimize the holding strength and to satisfy the remaining product requirements.

A kit of three grips was then manufactured to the specifications determined by the previous design spaces. The grips were tested to ensure they met product requirements and other observations were also made about their performance.

Finally, all substantial information collected throughout the duration of this integrated project was reexamined. Based off the findings, a decision was made whether the venture was worth pursuing and what would be the next steps of the project.

Background

The process of installing cable at a job site is comprised of four stages: installation, fishing, pulling, and termination. Contractors first install conduit which routes the path for electrical cables. Then, in a process called fishing, fishing tape is routed through the conduit in preparation to make connection with the actual cable to be installed. Then, during cable pulling, the cable is attached to the fishing tape and pulled back through the conduit as the fishing tape is retracted. Finally, in the termination stage, contractors connect the cable to the desired electrical boxes and/or machinery.

While contractors may deviate from this four-stage model, this is generally the most widely used method of installing electrical cable. A market has been built around this model, which provides all the necessary tools and accessories to facilitate the installation of electrical cable. The market includes many small competitors as well as some large-name competitors such as Greenlee, Grainger, and Southwire.

The third stage of the model, cable pulling, is comprised of two parts: the cable is first attached to the awaiting fishing tape, then the fishing tape is retracted through the conduit and the cable along with it. The method of attaching the cable to the fishing tape was observed during an on-site visit with Sycamore Engineering of Terre Haute. In this visit, a worker was observed as he connected the cable to be installed to the fishing tape. He did the process in three distinct steps. First, he stripped the cables of their jacketing (Figure 2). Second, he passed them through the eye-hole on the end of the fishing tape (Figure 3). Third, he held the wires in place with electrical tape (not shown).



Figure 2: Worker strips plastic jacket from the cable using a utility knife



Figure 3: Workers wrap cable strands through fishing tape eye

The worker was observed standing awkwardly, holding cable between his legs, while using a utility knife to strip the jacket cable; this posed a significant safety risk. Furthermore, the process required one worker to hold and wrap the cable strands while the other held the fishing tape. Altogether, this process took approximately 7.5 minutes, for a total of 15 man-minutes to attach the cables to the fishing tape. There is room for improvement, as this process may be completed faster and in a safer manner.

To facilitate the connection between fishing tape and cable, cable grips were created. The basic function of a cable grip is to create a connection between cable and fishing tape, in some way making a linkage with each of the two components. A variety of designs have been created by different competitors, including Greenlee's GatorGrip design, Southwire's Maxis Grip design, and Rectorseal's Wire Snagger design. However, each of these designs have significant drawbacks, discussed in the chapter on Market Research.

The proposed alternative to the previously mentioned designs is a cylindrical body with a tapered internal thread, also comprising an internally anchored loop of tensile wire (Figure 4).

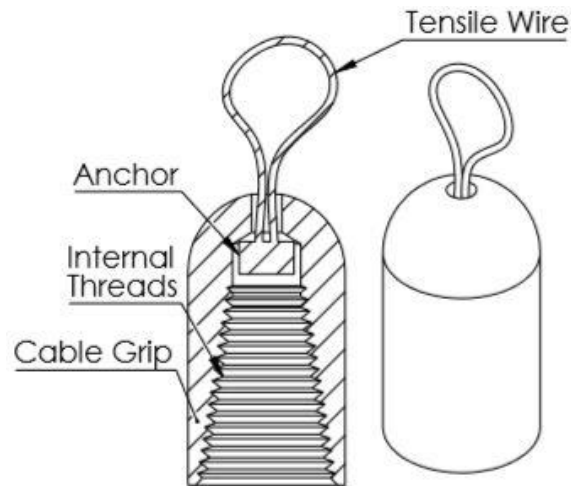


Figure 4: Proposed design of a new cable grip

The proposed grip will improve performance on the job site by providing a simple means of connecting the electrical cables to the fishing eye. The tensile wire shall connect to the fishing tape eye by a simple means of connection, most likely a small carabiner. Then, the threaded body may be screwed onto a bundle of cables resulting in a threaded connection between the grip and the cables' jackets. This entire process is estimated to be completed by one worker in under one minute.

Market Research

Before investigating the details of the design, it is worth determining if the design would have a place in the market or if competitors have already filled all market demand.

The electrical contracting industry is continuously growing; electrical contracting is a \$130 billion industry with over 650,000 electrical workers working for 70,000 electrical contracting firms in the United States alone (NECA), with over \$1 trillion in projects planned in 2017 (Labor Shortage). The industry is projected to continue expanding well into the futures\, and as it grows contractors are expected to look for lower cost alternatives to their current practices.

Pulls of large cable diameters, namely diameters greater than approximately 1.5", are typically performed using specialized pulling equipment such as mechanical cable pullers. Small pulls, namely installations done by hand without specialized equipment, are unlike large pulls in that they are performed across the entire industry since they do not require the up-front capital investment on equipment. Therefore, this product is predicted to be useful to all contractors across the electrical industry who install small-diameter cable bundles in conduit, with a particular emphasis in shorter pulls.

In a discussion with Tyler Dinkel, Field Project Manager of Sycamore Engineering, he validated the existence of the problem by stating, in regards to the time taken to prepare cable for installation, "I'll pay \$100 all day long for a solution to this problem." Dinkel stated this during an on-site visit to observe cable pulls (see "Observation of Cable Pull"). Dinkel further validated the existence of the problem when he expressed an excited willingness to test the first iterations of the product and provide feedback. When asked about prior solutions, Dinkel explained that his team would use Greenlee brand mesh grips for large diameter pulls, but they would have a habit of slipping if tension was lost in the middle of the pull. This was also confirmed by family members of the author who work in the electrical industry.

The mesh grip that Dinkel mentioned is shown in Figure 5. These grips, when compressed along the central axis, will expand in diameter. Likewise, when tension is applied to the assembly, the diameter will collapse onto the cable or cable bundle. This design is beneficial because as tension increases, so does the gripping strength. However, if tension is lost during the middle of the pull, or when initially starting a pull, the tension may be low enough that the grip slips off the cables. To combat the slipping issue, cable ties are oftentimes wound around the mesh to provide extra strength at low tensions.



Figure 5: Mesh Style Grip (Source: kitairu.net)

Mesh style grips are likely the most common pulling grip, being sold at many distributors under different manufacturers including Greenlee, SouthWire, ElecDirect, Hubbell, and Leviton. Retail price for mesh style grips is approximately \$182 for a 1"-1.25" diameter grip, with a breaking strength around 12,800lb (www.graybar.com).

Another common style of grips are crimp grips, which as their name implies, are crimped onto the cable to form a permanent connection (Figure 6). These grips fall short of success because they are not reusable, quickly becoming costly over the course of multiple pulls. Their cost increases if multiple cables are to be pulled through one conduit, as each grip may only hold a single cable of a specific diameter. Because multiple grips must be installed for a single pull, this also significantly increases the setup time, and becomes an inefficient solution, especially at low-tension pulls when multiple cables are needed per pull.



Figure 6: Crimp Style Grip (Source: www.graybar.com)

Crimp style grips are sold at many distributors under different companies' brand names, including Greenlee's Gator Grip, SouthWire's Simpull Head, and iTOOLco's Window Crimp. Retail price for crimp style grips is approximately \$26 each for a 1.25" diameter grip, with a breaking strength around 2000lb (www.graybar.com).

A third, relatively recent addition to the industry is Rectorseal's Wire Snagger shown in Figure 7. By inserting the cable through the open end, it folds back internal retractable teeth. When tension is applied to the assembly, the cable will engage the internal teeth, and force them into the cable jacket and cable. This design can only handle a single cable per grip, so multiple grips are still required per cable bundle, requiring a significant amount of upfront capital. Furthermore, should a laborer insert his/her finger into the grip, it would lead to either an injury claim or wasted time as the grip is removed.



Figure 7: Wire Snagger Grip (Source: www.sears.com)

Rectorseal is the only manufacturer of Wire Snaggers, without any similar design by competitors. They are priced at approximately \$687 each (www.amazon.com) for the 600 MCM model, which holds cables that are approximately 1.14" in diameter. The grips can withstand up to approximately 2200lb of continuous tension (www.rectorseal.com).

Beyond Rectorseal's Wire Snagger, the electrical industry has not had much innovation in pulling cables in the recent decades. It continues to show no sign of innovation, and the only other alternative design that has emerged recently is SouthWire's Maxis Grip (Figure 8). The Maxis Grip is a combination of a snagger-style grip and a mesh-style grip; the mesh operates as expected at high tensions and the snagging head will keep hold of the cable at lower tensions. While the design fixes the dilemma of losing grip at low tensions, it also suffers the drawback of only accepting a single, specifically sized cable, meaning that multiple heads of different diameters are required, and even duplicates of heads if multiple cables of the similar sizes are being pulled in a single run.



Figure 8: SouthWire's Maxis Grip (Source: southwiretools.ca)

SouthWire is the only manufacturer to sell anything similar to the Maxis Grip. They sell in a kit of four at a price of \$720, so approximately \$180 per grip (www.toolup.com). They can withstand up to 4000lb of tension (www.southwiretools.com).

Being in competition with the other solutions, the proposed design attempts to carve a niche by fulfilling the need to quickly complete successive low-tension pulls. Therefore, the product must excel where other competitors fall short in this need. Where competitor products may only be used once, the proposed design must be reusable. Second, where competitors require multiple grips for a single pull, the product should handle any combination of cables using only a single pulling grip. Third, the product must require equal or less setup time than competitors' products.

Table 1: Comparison of Expected Product Characteristics

	Wires	Reusability	Approx. Max Strength (lb)	Cost (\$)
Mesh Style	multiple	multiple	12,800	182
Crimp Style	single	single	2,000	26
Snagger	single	multiple	2,200	687
Maxis	single	multiple	4,000	180
New Product: Internal Thread Design	multiple	multiple	300	299

If the product is able to differentiate itself from the shortcomings of the competition by promoting time and cost savings on low-tension pulls, the product can leverage its functionality to achieve market success.

Intellectual Property Review

An intellectual property review was conducted to determine if the design would infringe on existing patents, since a conflict would have inhibited the production and sale of the proposed design. A conflict would occur if an existing patent or patent application makes claims similar to the proposed design and has been filed within the last 20 years, which is the duration of a utility patent in the United States. Existing patents and applications were examined as far back as the mid 1700's, and it was determined that the design does not infringe on designs currently covered by patents.

Search Methods

The review of intellectual property was conducted primarily through the United States Patent Office (USPTO) database with a few references through the Google Patent database. The USPTO database utilizes the Cooperative Patent Classification (CPC) scheme to organize its database entries based on the designs' purposes. Database entries can be browsed by their CPC Classification Code. As an example, the proposed design falls under the classification code **H02G1/083** which is comprised of its five components:

H	02	G	1	/	083
Section	Class	Subclass	Group		Subgroup

Wherein, each of the CPC Classification components corresponds to the CPC Classification Scheme's convention of organization:

Section H	Electricity
Class 02	Generation; Conversion or Distribution of Electric Power
Subclass G	Installation of Electric Cables or Lines, or of Combined Optical and Electric Cables or Lines
Group 1	Methods or Apparatus Specially Adapted for Installing, Maintaining, Repairing, or Dismantling Electric Cables or Lines
Subgroup 083	For Laying Cables Through Tubing or Conduit Using Pulling Means at Cable Ends

The USPTO database was searched for CPC Classification terms which included combinations of the following keywords: cable, pulling, conduit, wire, and through. The following CPC Classifications were examined:

B25B25/005 Implements for fastening, connecting, or tensioning of wire or strip for applying wire claps to hose couplings

F16B2/065 Friction-grip releasable fastenings using clamps and external screw-thread elements

F16G11/04 Means of fastening cables or ropes to one another or to other objects; Caps or sleeves for fixing cables on ropes with wedging action.

H02G1/081 Methods or apparatus specially adapted for installing, maintaining, repairing or dismantling electric cables or lines for laying cables through tubing or conduit using pulling means at cable ends, e.g. pulling eyes or anchors

H02G1/083 Methods or apparatus specially adapted for installing, maintaining, repairing or dismantling electric cables or lines for laying cables through tubing or conduit using lines, e.g. needles, rods or tapes

H02G1/085 Methods or apparatus specially adapted for installing, maintaining, repairing or dismantling electric cables or lines for laying cables through tubing or conduit using portable tools

H02G1/088 Methods or apparatus specially adapted for installing, maintaining, repairing or dismantling electric cables or lines for laying cables through tubing or conduit using pulling devices movable inside conduits

Search Results

In total, approximately 700 granted patents and 200 patent applications were examined for similarity to the proposed design. The designs most similar to the proposed design were located and documented below, in the order of date filed.

Patent No. 4,123,133

Oct. 31, 1978

Method and Apparatus for Applying a Connector to Electrical Conductor Strands

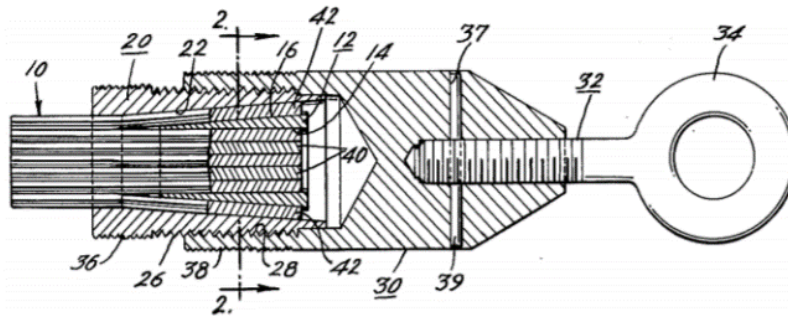


Figure 9: Patent 4,123,133 – Method and Apparatus for Applying a Connector to Electrical Conductor Strands

This design is dissimilar to the proposed design because it utilizes two separate components (20 and 30), opposed to a single body, to achieve a compression on the cable or cable bundle (10).

Pub. No. US 2007/0001157 A1

Jan. 4, 2007

Conduit Leader

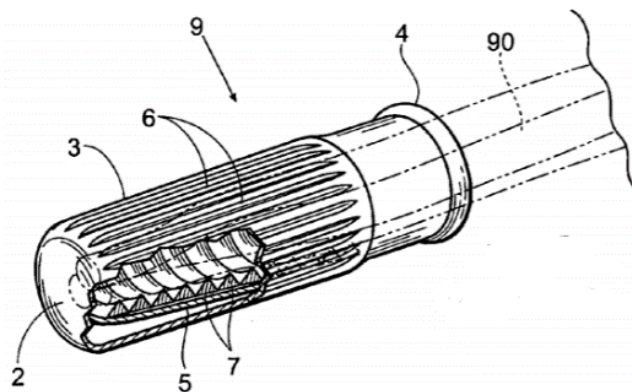


Figure 10: Pub. No. US 2007/0001157 A1 - Conduit Leader

This design has similar traits to the proposed design, such as the internal tapered threads (7) and open end (4) to connect with the cable or cable bundle (90). The design claims:

“A device for guiding a flexible member through a conduit, said device comprising a leader body having an open end and closed end...”

However, the proposed design does not have a closed end and therefore does not infringe upon the patent application. Instead, it has an open anterior for the passage of steel tensile cable used to pull the body, while the design shown here has no method of pulling the body and instead must be pushed through the conduit which is inherently different.

Patent No. US 7,478,794 B1 **Jan. 20, 2009**
Apparatus and Methods for Gripping an Elongated Item

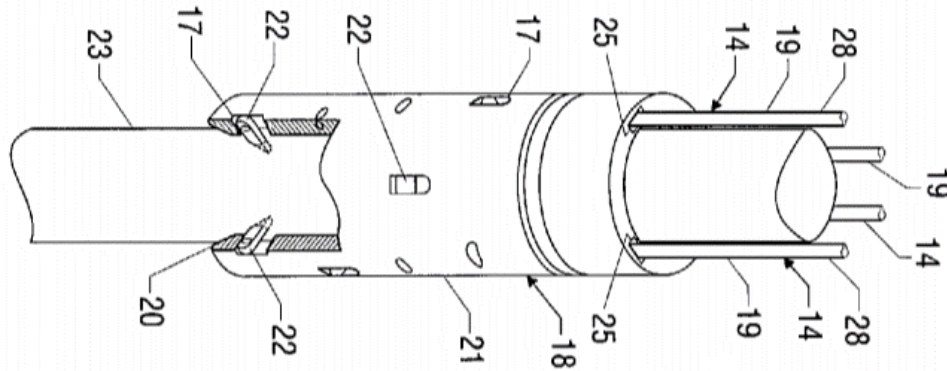


Figure 11: Patent No. US 7,478,794 B1 - Apparatus and Methods for Gripping an Elongated Item

This design is dissimilar to the proposed design as it does not utilize internal threads, but rather uses pivoting members (22) to grip a single cable (23) while under tension. This design is used by Rectorseal's Wire Snagger™.

Pub. No. US 2012/0090145 A1 **Apr. 19, 2012**
Elongate Member Attachment Apparatus and Method of Use Thereof

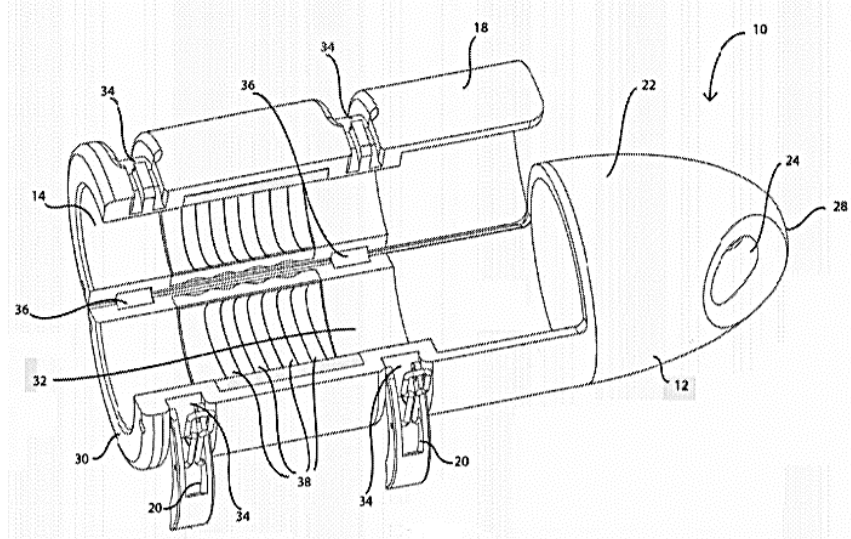
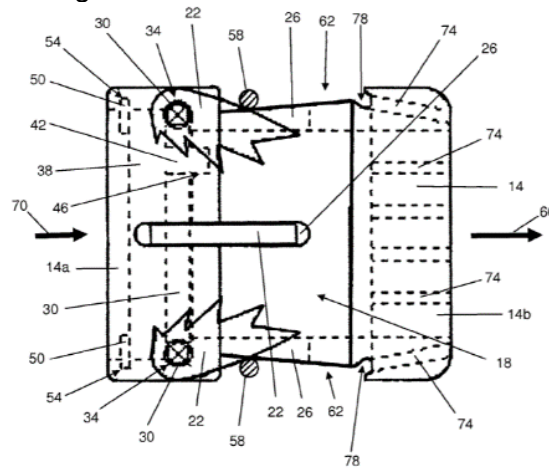
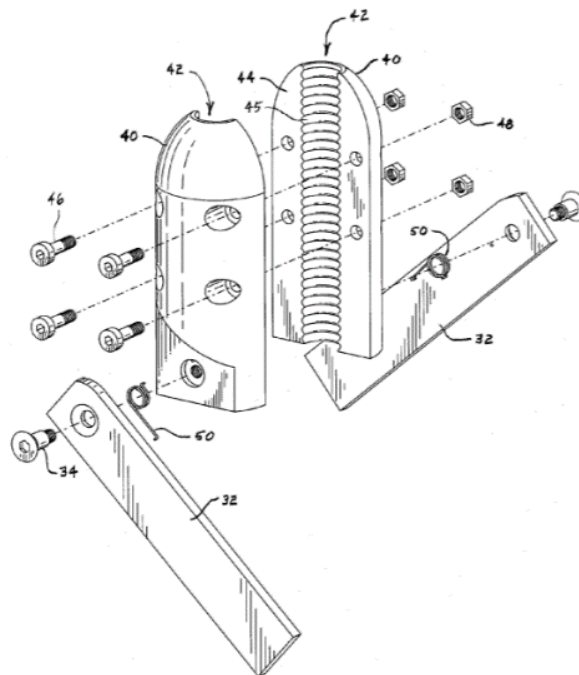


Figure 12: Pub. No. US 2012/0090145 A1 - Elongate Member Attachment Apparatus and Method of Use Thereof

This design is dissimilar to the proposed design because it utilizes a clamping mechanism and hinged member to achieve compression of the cable or cable bundle against internal threads.

Patent No. US 8,459,612 B2 Jun. 11, 2013*Device for Gripping and Installing Wire***Figure 13: Patent No. US 8,459,612 B2 - Device for Gripping and Installing Wire**

This design is dissimilar to the proposed design as it does not utilize internal threads, but rather uses toothed pivoting members (22) to grip a single cable (not shown) while under tension. This design is used by Southwire's Maxis® Grips™ Pulling Heads.

Patent No. US 8,648,254 B2 Feb. 11, 2014*Device and Method for Stringing Overhead Cable***Figure 14: Patent No. US 8,648,254 B2 - Device and Method for Stringing Overhead Cable**

This design is dissimilar to the proposed design as the internal thread (45) is not tapered, and the components are held together with fasteners (46). Further, the arm components (32) are in place to help run cable overhead instead of within conduit.

Patent No. US 9,027,908 B1
Field-Installable Pulling Eye

May 12, 2015

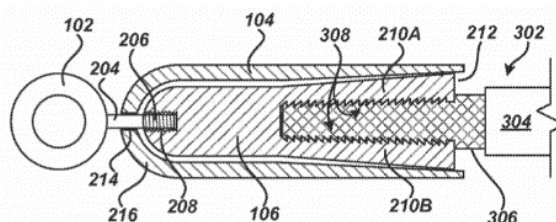


Figure 15: Patent No. US 9,027,908 B1 - Field-Installable Pulling Eye

This design is dissimilar to the proposed design as the external component (104) and screw component (102) act upon and draw in a collet (106) which compresses onto the cable or cable bundle (304).

Pub. No. US 2015/0137053 A1

May 21, 2015

Device for Improving the Attachment of Wires, in Particular Electric Wires, to Facilitate Pulling of Same in Conduits

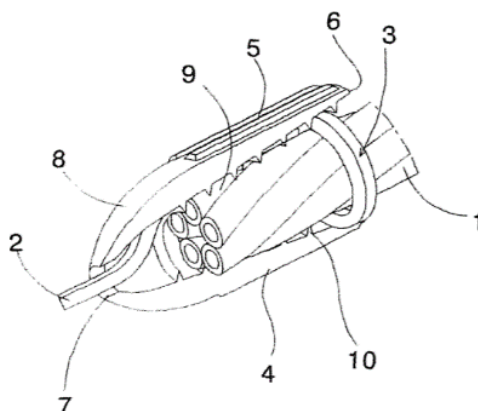


Figure 16: Pub. No. US 2015/0137053 A1 - Device for Improving the Attachment of Wires, in Particular Electric Wires, to Facilitate Pulling of Same in Conduits

This design is similar to the proposed design as it comprises a piece with a cylindrical body (8) about a longitudinal axis that envelops internal threads (10). A loop of steel cable (3) comes out the front of the body (2) and is used to add additional grip to the cable while under tension. The design makes claims similar to the proposed design:

“A device for improving the attachment of wires, particularly electrical, for facilitating their pulling in conduits or tubes, comprising an endpiece, characterized in that the end-piece has a body of revolution having a longitudinal axis, comprising a front part and a rear part, the front part being a convex envelope of revolution about the aforementioned axis, the rear part having a hollow in the shape of a cone frustrum whose large base coincides with the base of the rear part, the aforementioned cone frustrum comprising on its interior surface a tapered thread and the aforementioned front part having means for enabling an attachment.”

However, the USPTO has listed the application’s status as “Abandoned – Failure to Respond to an Office Action” as of June 20, 2016.

Patent No. US 9,178,341 B2
Fishing Adapter

Nov. 3, 2015

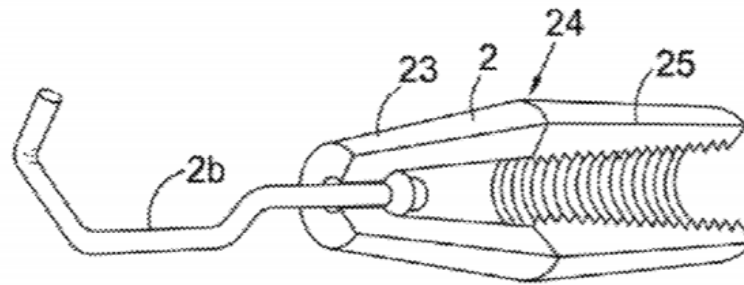


Figure 17: Patent No. US 9,178,341 B2 - Fishing Adapter

This design is dissimilar to the proposed design as it makes claims of a drill bit connector (not shown) that, when used in conjunction with the adaptor (24), allow drilling through masonry and stone without twisting or damaging the cable (not shown).

Patent No. US 9,537,293 B2
Wire Pulling Head Apparatus with Crimp Zone Indicators and Method of Using Same

Jan. 3, 2017

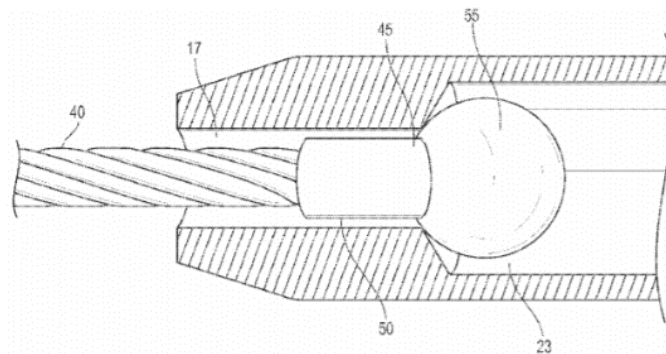


Figure 18: US 9,537,293 B2 - Wire Pulling Head Apparatus with Crimp Zone Indicators and Method of Using Same

This design is dissimilar to the proposed design as it utilizes no internal threads, but rather displays zones (not shown) that, when crimped, hold tight against the inserted cables.

Intellectual Property Conclusions

The proposed design does not infringe upon granted patents or patent applications. The most similar patent application is **Pub. No. US2015/0137053A1**, and was filed on May 21, 2015. The patent makes claims similar to the proposed design, however USPTO considers it abandoned as of June 20, 2016 by reason of "Failure to Respond to an Office Action." Therefore, the proposed design will not infringe upon the patent application.

However, without genuine novelty in the design, the proposed design is unable to be protected by intellectual property since the claims made in **Pub. No. US2015/0137053A1** are now considered publicly disclosed due to filing an application, albeit abandoned. Therefore, if intellectual property is sought, the proposed design should be modified to include novel design ideas not seen in previous applications.

Marketing Strategy

The marketing strategy behind the new device to pull cables relies on the successful small-scale adoption of the product followed by increased customer demand and finally distributor support. The product is expected to be sold at a discounted price to distributors (GraybaR, Grainger, Zoro, Fastenal), who then sell the product at retail price to customers. Following is a brief discussion of the marketing strategy based on the “7 P’s of Marketing,” i.e. Product, People, Promotion, Price, Place, Process, and Physical Evidence.

Product

The first product under development is a palm-sized cable grip with internal tapered threads, however marketing will focus less on the physical product and more on the intangible benefits of using the product – the time savings. As such, it is important to communicate this value and show customers the time saved on each and every pull. The reliability and durability of the product shall also be presented to the customer, which saves the customer the replacement costs of alternative solutions.

The product shall come in a kit of multiple sizes to ensure a large range of cable bundle diameters are compatible with the proposed design. This flexibility allows the product to be marketed to customers as an all-in-one solution for small-diameter cable pulls.

People

The targeted market segment can generally be described as electrical contractors who have a need to pull cable with less than 350 pounds of tension. These contractors operate in HVAC installation, fiberoptic installation, power installation, and underground utilities. The conduit is the same across all industries, therefore the product is as viable a solution for installing fiberoptic cables as it is to run HVAC and power-transferring cables.

The author will handle the early marketing efforts, which may evolve into a complete campaign depending on product success. The author will make trips to key job sites and industry conventions in attempts to spread awareness and demand for the product. Therefore, the author’s knowledge of the industry as well as his personable character are key assets to the success of the marketing efforts.

The author will also be in charge of customer relations and customer service, creating a positive experience for customers and marketing the brand that is being built. In turn, product demand is expected to increase as customers spread product referrals among the industry.

Promotion

The first sales are expected to be made through on-site visits and product demonstrations. Then, it is expected that after a sufficient number of contractors are using the product, demand may be created by showcasing the improvements the product has created for other customers and sharing testimonials. Potential users may then be directed to purchase the product at their local distributor, in tandem with providing information about previous sales to distributors, in attempts to get the product stocked within stores.

The rising customer demand is expected to increase the pressure for distributors to stock the product within their stores. Once the product is on distributors’ shelves, distributors are expected

to perform a portion of the marketing, featuring the product on the front page of their websites and advertising in their catalogs, as shown in Figure 19.

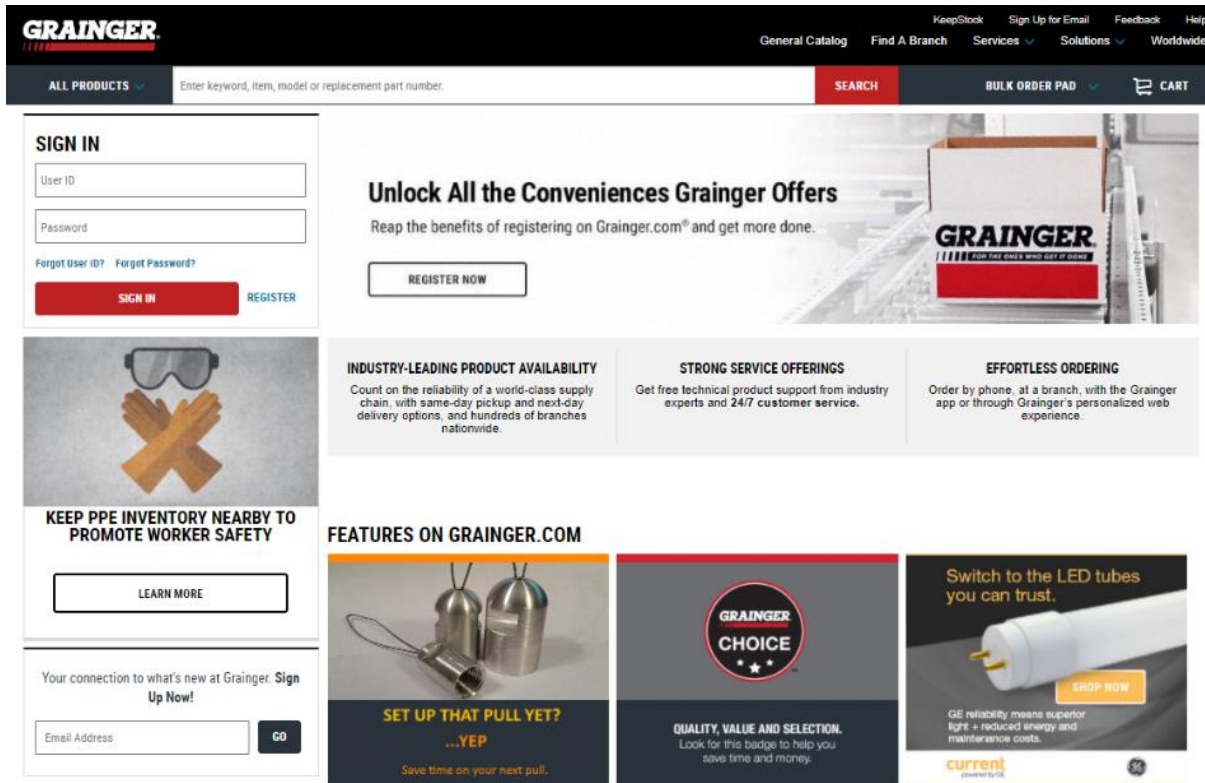


Figure 19: Grainger Homepage with Example Product Ad (Source: www.grainger.com)

E-content will also play a role in promoting the product. Facebook, YouTube, and Twitter have advanced algorithms which advertise to customers based on the data collected about the customer, which will be used to target the product towards the customer segments.

Price

In a discussion with Sycamore Engineering (see “Meeting with Sycamore Engineering”) it was suggested that the customer would like to pay approximately \$300 for the kit of pulling grips (the product). Thus, it is suggested that the product has a listing price of \$550, which may be discounted to differing amounts for each distributor based on quantity purchased and reputation of the distributor.

For example, a reputable distributor might receive 50% off listing price plus an additional 10% off (after distributor discount) if ordering at least 100 units. Therefore, if ordering in quantity, the distributor may purchase at \$247.50 each and sell at their desired price (recommended retail price of \$299). Other discounts may be applied depending on the order size, special events, seasons, and if buying kits versus individual grips.

A lowest-retail-price limit may also be enforced in contracts with distributors so that the product's retail price is kept high enough to allow an increase of listing price if the product demand is great enough.

Place

Thought was given to the location where advertisements would be placed. Performing job-site visits alone would be too slow to stimulate product demand, and a blanket-style placement of advertisements, such as advertising on Google and other high-traffic areas, would be inefficient in reaching many non-customers. In order to efficiently reach the target customers, advertisements shall be placed in trade magazines such as Electrical Contractor (Figure 20) and booths shall be rented at industry conventions such as the ElectroExpo (Figure 21). Sycamore Engineering, for example, attends industry conventions.

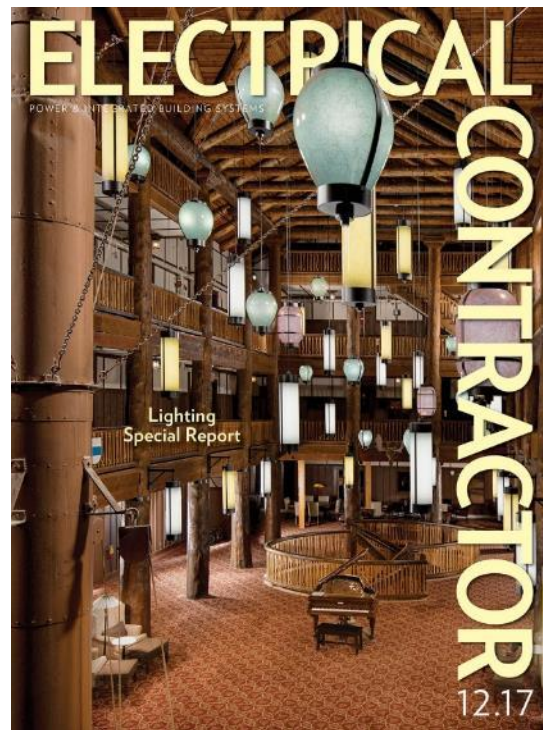


Figure 20: Electrical Contractor Magazine, Issue December 2017 (Source: www.ecmag.com)



Figure 21: Electro Expo 2018 Trade Show (Source: www.electroexpo.org)

A product landing page shall be created for contractors interested in learning more about the product. This landing page will showcase the durability of the product, the reusability, the savings, as well as testimonials. The landing page is a critical component of the marketing efforts, as it behaves just as an advertisement in a magazine except the customer is already aware of the product and is now seeking information on the product. The landing page is a way to set the

product apart from competition, and serves as a point of contact for distributors interested in stocking the product on their shelves.

Process

The success of the product will be accelerated through reputable distributors, such as Fastenal, because distributors already have the capital to absorb the initial costs of bringing a product to market and the distribution network to quickly bring the product across the United States. Therefore, beyond the initial on-site visits and direct sales to customers, product delivery will be handled through distributors. Distributor partnerships would imply that the product may not be sold outside of the distributors' domains, otherwise it would be competition against the distributors. In this case, the benefits are far greater so the product shall be manufactured and supplied to distributors. Defects and product feedback will be taken directly from the customer, and a webpage will also supply contact information for the product.

Physical Evidence

Physical evidence refers to everything the customer is expected to interact with, including the physical environment providing the product. However, the layout of retail stores is beyond the scope of this project, therefore physical evidence in this case shall refer to the project packaging and branding.

Packaging for the product shall be durable and present a look of durability, as it will likely end up in a toolbox bashing against other tools. It must resist fracture and stand up to harsh demand just like the product it houses.

The product's brand identity shall also be that of a durable product. It shall resemble characteristics of strength and rigidity, promoting customers' trust in the product. The product, through successful usage, shall establish a history of integrity and quality, which will prove beneficial in future marketing campaigns and advertising the product.

Business Model Canvas

The proposed business model canvas is aimed at a single product, without plans to expand into a multiple product business. This leads to specific strategic choices, such as outsourced manufacturing, since manufacturing in house would prove either too costly for specialized equipment or too wasteful to dedicate a versatile machine to a static, simple part. Exit strategies are presented under the section of Revenue Structure.

Value Proposition

The proposed product eliminates cable preparation to save the customer time and labor.

Customer Segments

The product's benefits are targeted towards anyone performing low-tension pulls of cable through conduit. This includes utility companies who install underground electrical, phone, and fiber optic lines. HVAC and plumbing companies also route cable through buildings for equipment installation. Electrical contractors are also targeted customers since they route cable when installing electricity in buildings.

Customer Relations

The U.S. has multiple electrical contracting trade shows including the Independent Electrical Contractors (IEC) and National Electrical Contractors Association (NECA) conventions. Booths held at the events will spread awareness about the product and demonstrate its value to the public.

Advertisements will be targeted towards customers and posted in locations with high customer traffic. These advertisements will be posted on specific google searches, trade webpages and forums, and trade magazines such as EC Mag.

Customers requiring product assistance may submit queries over phone or through a designated email address.

Channels

Some early sales will be completed at on-site product demonstrations to contractors.

Sales will also be completed through reputable distributors and retailers. Distributors may include Fastenal, Grainger, GraybaR, Zoro, and others.

Key Partners

Manufacturers are the producers of the product and are vital to the business. Strong, communicable relations with manufacturers help to control the product's quality and minimize production issues.

A majority of sales will be through distributors and retailers. Partnerships with distributors will allow product sales on a national level.

Early adopters are vital for the first sales and to establish product credibility for future sales. Some of these early adopters will be personal relations such as friends and family. Others will be

references from general partners such as the Rose-Hulman Institute. Early adopters will receive exclusive promotional offers as incentives.

To facilitate advertisement in areas of high customer traffic, partnerships will be held with trade shows, trade magazines, and targeted websites.

Key Activities

Advertising, promoting, manufacturing, distributing, and selling are the fundamental activities of the business. Sourcing manufacturers and distributors are supporting activities.

Key Resources

Customer data gives insight to improve the product and foster repeat customers. Therefore, customer knowledge, voice of the customer, and industry experience are valuable assets that give the venture a unique advantage over competitors.

Intellectual property and patents on the new product create an entry barrier against competition. This unique advantage is also necessary for the first of two proposed exit strategies.

Cost Structure

Initial costs include the intellectual property filing fees and the manufacturing setup fees.

Recurring costs include manufacturing rental and material, distributor fees, employee wages, insurance, and product advertisement.

Revenue Structure

Revenue will be generated by sales that occur initially through on-site visits and later through distributors.

The first of two exit strategies is the direct sale/lease of intellectual property to an existing competitor such as Greenlee or Southwire. This strategy circumvents the needs to source manufacturers and distributors. However, a customer base showing product demand is needed to convince competitors to invest in the intellectual property.

If intellectual property is not held, the secondary exit strategy is the sale of the business to an existing competitor. Competitors' interest would be in the key resources of the business: established customer lists, customer data, and existing manufacturing and distribution chains. The purchaser would also absorb annual profits.

Table 2: Business Model Canvas

Key Partners	Key Activities	Value Proposition	Cust. Relations	Cust. Segments
Manufacturers Distributors Contractors / early adopters Trade shows, magazines and websites	Promote product Distribute / sell product Source manufacturers, retailers and customers	Eliminate cable preparation Save time and labor when pulling cable	Product demos at trade shows and on-site visits Advertisements in trade magazines, trade sites and google ads Personal assistance hotline and email Website / Landing Page	HVAC contractors Plumbing contractors Electrical contractors Utility companies
	Key Resources		Channels	
	Intellectual property Industry experience Customer base		Distributor sales Direct sales	
Cost Structure		Revenue Structure		
Advertisement (web, magazines, trade shows, Google, e-media) Manufacturing Retailer Fees, Employee Wages, and Insurance Intellectual Property Costs		Sales Exit strategy		

Solicitation of Product Requirements

The product requirements stem from knowledge held by the author, from industry standards, and from communication with potential customers during jobsite visits. For example, it was already known that the maximum bend radius for any turn in conduit is 90 degrees, so the product shall be able to navigate any bend of equal to or less than 90 degrees. In addition, functional needs which describe the behavior of the product exist, such as – the product shall connect cables to a means of pulling. Furthermore, some needs described the goals of the product, such as – the product shall reduce setup time. Still, other needs were solicited by direct communication with customers. Direct communication with potential customers was invaluable as it provided insight that would have otherwise been missed. For example, the product shall be operable while wearing gloves. Following is the complete list of product requirements, alongside an explanation to the purpose and measurability of the requirements.

The first series of requirements may be considered functional. They describe the operation of the product, mainly that the product shall establish a physical connection between the cable and means of pulling. The process should also be more efficient than existing processes, if it is to be adopted by customers as a substitute to their current solution.

Req 1. The product shall establish a physical connection between cable and pulling means.

Req 2. The product shall establish the connection in less than fifteen man-minutes of labor.

Req 3. The product shall terminate the connection in less than five man-minutes of labor.

The following requirements stem from conversations with customers. In “Meeting with Sycamore Engineering,” the product was described as a solution for small pulls, mainly those operating in a conduit of less than 2” in diameter. With this size of conduit, the expected maximum tension forces are estimated around 250 pounds based on the assumption that the product is intended for hand pulls, not machine pulls. In addition, a concern was expressed about the product fitting in PVC conduit, as it could possibly shrink in diameter when bent to a maximum of 90 degrees. Therefore, the product needs to operate correctly in multiple varieties of conduit, especially around bends up to 90 degrees. Furthermore, one favorable attribute of the product was determined to be its reusability. This was confirmed through customer opinion, and the product is desired to be reusable as many times as possible until lost or missing. However, material limitations limit the product to a finite lifespan, so a 20-time use is determined satisfactory unless otherwise deemed inappropriate in the future.

Req 4. The product shall navigate conduit at least ½” in nominal diameter.

Req 5. The product shall navigate conduit at most 1 ½” in nominal diameter.

Req 6. The product shall sustain at least 250 pounds of tension.

Req 7. The product shall navigate up to 90 degree bends in conduit.

Req 8. The product shall be compatible with PVC, EMT, RSC, and RMC conduit.

Req 9. The product shall be reusable at least 20 times before replacement.

Customers also mentioned that the installation of conduit and cable is regulated by the National Electric Code (NEC). The NEC declares that for cable to be safely installed, its jacket must remain intact and none of the internal wire exposed inside the conduit. The conduit must also meet NEC requirements, as it may not be kinked, marred, or otherwise damaged in any discernable way.

Req 10. The product must not damage the integrity of the cable outside of the gripping area.

Req 11. The product must not damage the integrity of the conduit.

When questioned about the standard operations in preparing, running, and terminating cable, customers pointed out that cut-resistant gloves are mandatory in all operations on-site. Oftentimes, lubricant is also used in the preparation of cable. To be effective, the product needs to be compatible with both of these standard practices, being usable with gloves as well as in the environment of lubricant. Customers also expressed the necessity of the solution to be simple enough to be used without specialized training. Expanding on this, specialized tooling would require specialized training and therefore should also be excluded. Customers also mentioned the solution should not otherwise inhibit the process or make it any more difficult, specifically in the amount of friction added to the process of pulling cable.

Req 12. The product shall be operable while wearing gloves.

Req 13. The product shall be operable alongside the addition of lubricant/grease.

Req 14. The product shall be usable by the general customer without specialized training.

Req 15. The product shall be operable using tools already readily available to the customer.

Req 16. The product shall add less than 20 pounds of frictional force to the pulling operation.

Lastly, it was already known that the product must operate with a variety of bundled cable combinations. It was then decided that the diameter of the cable bundle would be the metric in determining the effectiveness of the product. Based on NEC regulations, the expected extremes of cable bundle diameters were found, and used as the following product requirements.

Req 17. The product shall be compatible with cable bundles at least $\frac{1}{4}$ " in diameter.

Req 18. The product shall be compatible with cable bundles at most $1 \frac{1}{4}$ " in diameter.

The fulfillment of all product requirements would be considered a technical design success. However, technical design is only one component of actual product success. For example, customer satisfaction is also a component of product success since this influences the purchasing behavior of the customer. Therefore, these product requirements are at best an approximation of the product's completeness and/or success, and are a starting point for measuring the actual success of the product.

Prototypes and Design Process

This section details the design decisions in selecting the proposed design. Brainstorming and sketching sessions were conducted to develop general ideas of the basic geometry of the design. Then, the ideas were developed and drawn in SolidWorks. Based on the drawings, these designs were manufactured in the Rose-Hulman Machine Shop as a series of proof of concepts in order to test the viability of different characteristics. Then, the final proposed design was designed in two parts: the interior components, such as the threads and the resulting holding strength of the design, and the exterior components, such as the shape and ability to navigate around conduit bends. The former was tested in a design of experiments, and the latter was determined through a series of design spaces.

Proof of Concepts

Prior to the rigorously examined proposed design, proof of concepts were created to determine what would be feasibly manufacturable at the Rose-Hulman Mechanical Engineering Machine Shop. This stage of rapid prototyping revealed early design challenges that would have been costly to manage in the later design processes. The quick iterations of the design allowed for insight about the geometry and material selection that would otherwise not have been easily gained.

Figure 22 demonstrates the first and second iterations of the design. The first iteration was fabricated in a 3D printer as a proof of concept that a device with internally tapered threads would be able to compress cable bundles. A through-hole was later added to allow for the insertion of a screwdriver to use as a lever-arm. It featured a hexagonal exterior, because it was assumed that an electrician may also have a wrench on their person that can be used to tighten the grip onto the cable bundle. The geometry of the internal threads were designed identical to the geometry of standard pipe taps.

The first iteration, a rapid prototype, was created on a MakerBot 3D Printer out of ABS plastic. This iteration, though too fragile to handle the stresses induced by compressing cable, assisted with planning for manufacturing and provided insight to the general size and shape. The second iteration was identical to the first except it was fabricated from an ultra-machinable steel, namely 12L14. However, the durability of the 12L14 made it difficult to incorporate a standard pipe thread, as the pipe tap would often hang up on the material and risk fracture of the tooling. The final depth of the thread was much less than desired, therefore, to save time and move to the next iteration, a through-hole was not incorporated into this second iteration.

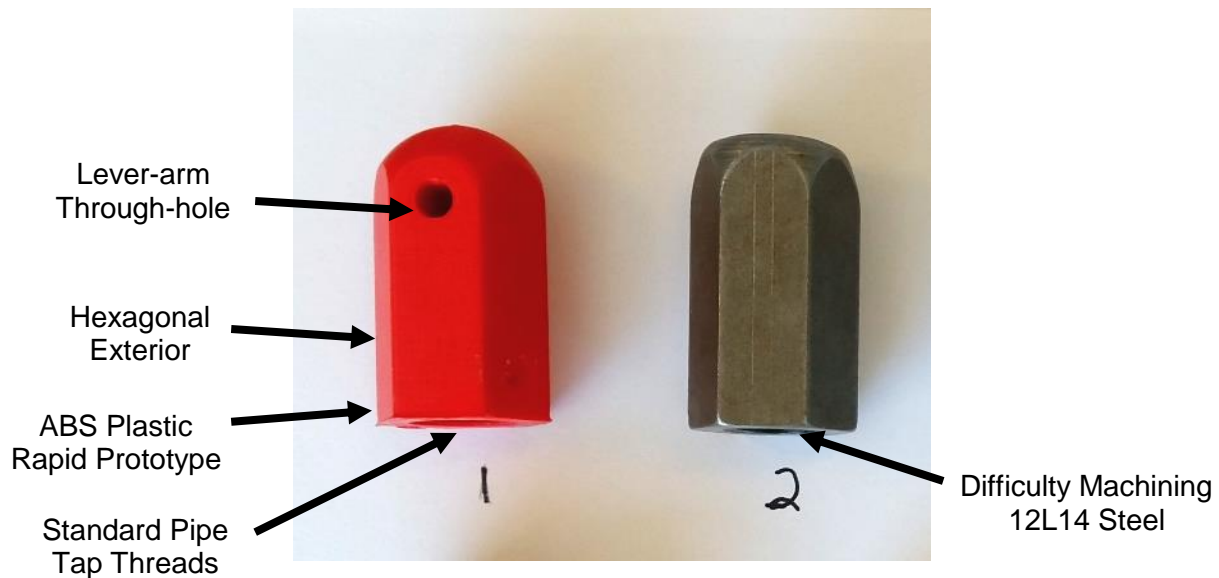


Figure 22: Iterations 1 and 2

Aluminum was selected as the next material of choice for prototyping due to its availability and inexpensive costs. Aluminum was also predicted to demonstrate enough strength to hold against the hoop stresses (those tangent to the central axis) experienced while under load. Figure 23 demonstrates iterations 3 and 4. The hexagon exterior was determined to inadequately fit within conduit, so a rounded exterior was determined to be a better choice. Iteration 3 has the addition of two eye-holes that allow the user to gauge the depth of the cable bundle, and could possibly be used as indicators as to whether the bundle is inserted an adequate depth. To accommodate for the longer length, multiple pipe taps had to be used as a single tap was unable to reach the full depth of the grip. Therefore, the internal geometry of the iteration is comprised of three tapers: a large diameter taper, which steps into a medium diameter taper, which steps into a small diameter taper. The exterior also featured a knurled surface to allow for better grip by the user.

Iteration 4 was similar to the previous iteration, except it featured one less internal taper as it was determined that the cable bundle would get caught on the ledge that occurred at the transition from one taper diameter to the next (Figure 24). Therefore, it was believed that cutting out one of the two internal ledges would eliminate part of the issue. The result was a shorter design with one less depth gauge.

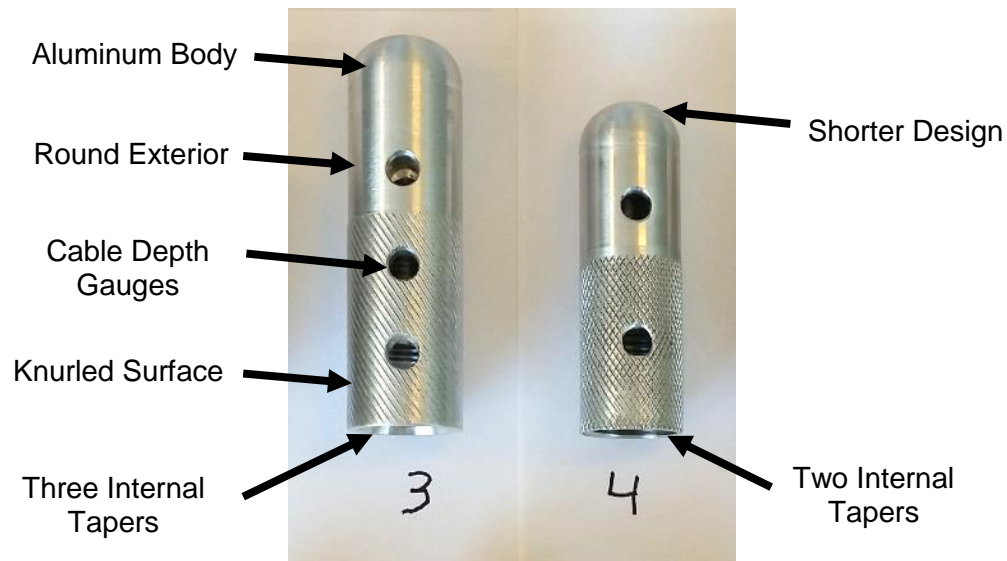


Figure 23: Iterations 3 and 4

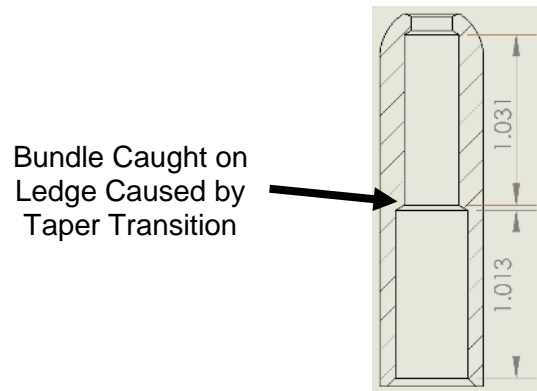


Figure 24: Cross-Section of Iteration 4, Prior to Installment of Taper and Threads

The cable bundle would still jam against the internal transition between taps, so iterations 5 and 6 were attempts at eliminating the internal transitions by utilizing extra-length pipe taps (Figure 25). Since the focus was to determine the feasibility of a single internal taper, much of the exterior geometry was left unfinished in these iterations.

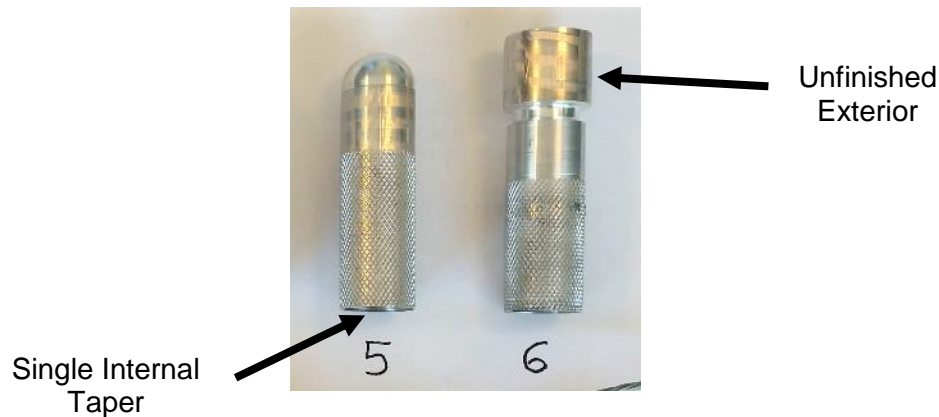


Figure 25: Iterations 5 and 6

The success of a single internal taper prompted a transition to a W2 tool steel in iteration 7 (Figure 26). Even though the exterior was manufacturable, the pipe taps were still unable to reach the required depth without getting stuck and shattering inside the steel body. Therefore, it was decided that if steel would be the selected material, the grip would not be manufacturable by a standard tap and a single-point thread is the only likely alternative to manufacturing.

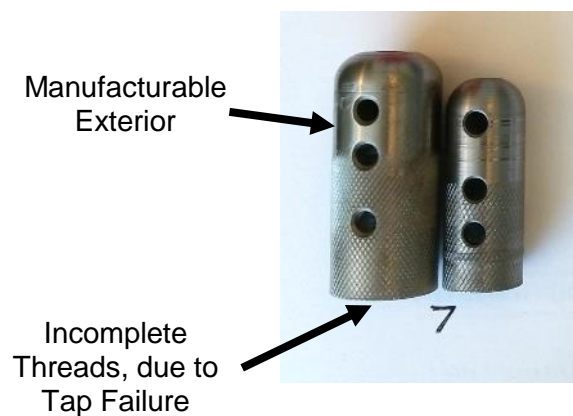


Figure 26: Iteration 7

Figure 27 demonstrates a transition back to aluminum as the viability of single-point threading is assessed. Iteration 8 was an attempt at creating an internal tapered thread given the equipment in the Rose-Hulman machine shop. The success of iteration 8 prompted iteration 9, in which two identical grips were manufactured using single-point internal threads. Iteration 10 was then created as a shorter version of the previous iteration. Single-point threading also allows flexibility in the design of the internal threads, as this method allows control over the shape of the teeth, the pitch of the teeth, and the taper of the teeth, which would otherwise be uncontrollable given the standardized geometry of pipe taps.



Figure 27: Iterations 8, 9, and 10

Iteration 10 was then briefly tested on a Riehle PH-300 tensile tester, fitted with an Admet Gauge Buster digital readout, located in the Rose-Hulman machine shop. The grips were able to hold a bundle of cable inserted to maximum depth up to approximately 60 pounds of tension. Clearly, the internals needed work in order to increase the maximum holding strength, as this would not meet the product requirements, where the goal was to hold 400 pounds of tension.

Experimentation of Hold Strength Based on Grip Geometry

A three-factor design of experiments (DOE) was conducted to determine the effects of the various grip geometries to the maximum holding strength. This DOE showed that the effects of one factor was much greater than the others, so that factor was assumed to be extremely important while another two-factor DOE was conducted for better accuracy in producing a regression equation, relating relevant geometries to the holding strength. The DOE assumes the effects of the three factors to be linearly correlated to the holding strength.

Selected Factors

The three factors selected for testing were **A**: Pitch, **B**: Taper, and **C**: Tooth Angle, shown in Figure 28. The three factors were assumed to linearly affect gripping strength. However, with more time and money it would be worthwhile to explore the linearity of the relationships. With the assumption of linearity, the final linear regression equation could be constructed by testing a high (+) and low (-) value for each of the factors.

Pitch **A** of teeth was predicted to have an effect on the holding strength because it was hypothesized that a larger surface area of contact between the grip and cable would positively affect grip strength. **A** is measured in threads-per-inch. The low value **A-** was selected to be 14 TPI as it was found to have tooth crests with the same height as the approximate thickness of the tested cables' jacket coatings. The high value **A+** was selected to be 20 TPI, since it would result in a marginally larger number of engaged teeth at the sacrifice of tooth engagement depth.

Taper **B** was predicted to have a similar effect on holding strength. A low taper would have more contact area with the cable than a high taper and was predicted to result in larger grip strength. Therefore, it was hypothesized that Taper **B** would correlate negatively with gripping strength. **B-** was selected to be 9 degrees as it was the smallest taper possible with the preexisting geometry constrictions. **B+** was selected as 15 degrees because it was marginally greater than **B-** while still being of reasonable depth.

Tooth Angle **C** describes the backward-tilt of the teeth in relation to perpendicularity to the Taper **B**. It was predicted that Tooth Angle **C** would positively correlate to the gripping strength, because as angle **C** increased the top face of each tooth would become more perpendicular with the axis of cable tension, increasing the frictional forces that resist cable pullout. The low value **C-** was chosen to be 0 degrees, i.e. perpendicular to **B**. The high value **C+** was chosen to be 18 degrees.

While other factors, such as material and tooth roundness, could also have an effect on the holding strength, they were deemed negligible when compared to **A**, **B**, and **C** and were not tested.

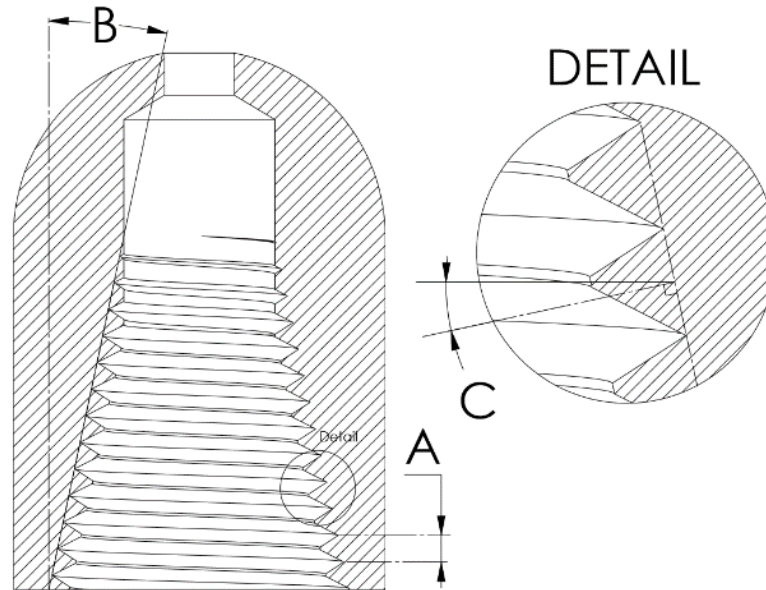


Figure 28: Geometry Callouts of Factors A, B, and C

Manufacturing and Verification

A total of 8 grips were manufactured, representing each possible combination of factors. For the list of combinations, see Table 3. Each grip was stamped with its geometry. For example, a grip that reads:

14 TPI
15°
-0°

would have values 14 threads per inch **A-**, 15 degrees taper **B+**, and 0 degrees tooth angle **C-**. The tolerances were checked after manufacturing. Pitch **A** is discrete and required no tolerance check. Taper **B** is accurate to +/- 1 degree on each grip. Angle **C** is accurate to +/- 1 degree. **C+** is labeled on the grips as “-9”, however the actual angle is twice this amount. **C-** reads as “-0” and is still a 0 degree offset to the perpendicular of taper **B**.

Table 3: All Possible Factor Combinations

	(A) Pitch [14 or 20 TPI]	(B) Taper [9 or 15 deg]	(C) Angle [0 or 18 deg]
Grip 1	+	+	+
Grip 2	+	+	-
Grip 3	+	-	+
Grip 4	+	-	-
Grip 5	-	+	+
Grip 6	-	+	-
Grip 7	-	-	+
Grip 8	-	-	-

Testing Procedure

Grips were selected to be tested at random through a number generator. The grip in question was loaded onto three 3-guage stranded copper cables, selected because it was a standard combination of cables at the on-site visit with Sycamore Engineering. The grip was twisted onto the cables to a torque of 50 inch-pounds, a torque slightly greater than hand-tightening, measured using a torque wrench for an accuracy of approximately ± 5.8 in-lb.

The grip was then inserted into a tensile tester maintained and calibrated by Mike Fulk of the Mechanical Engineering Department. The bottom claw of the tensile tester held onto the cables, while the top claw grabbed the pulling grip via a carabiner, see Figure 29. To negate strain rate effects, each grip was tested at a pull rate of 2 inches per minute. The maximum force was recorded by the digital readout.



Figure 29: Tensile Testing Setup

The failure mode of most pulls was deformation of the threads produced in the cable jacket (see Figure 30). A rare few failed by method of ultimate strength, where the jacket eventually tore and stripped off the cable (see Figure 31).

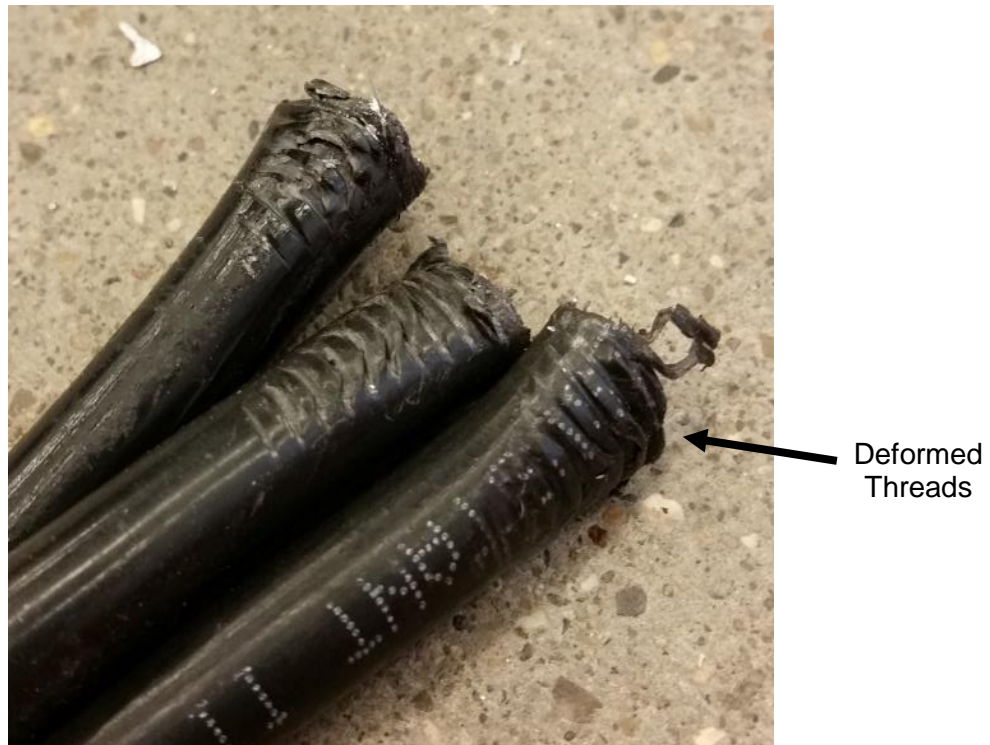


Figure 30: Deformation Failure of Threads

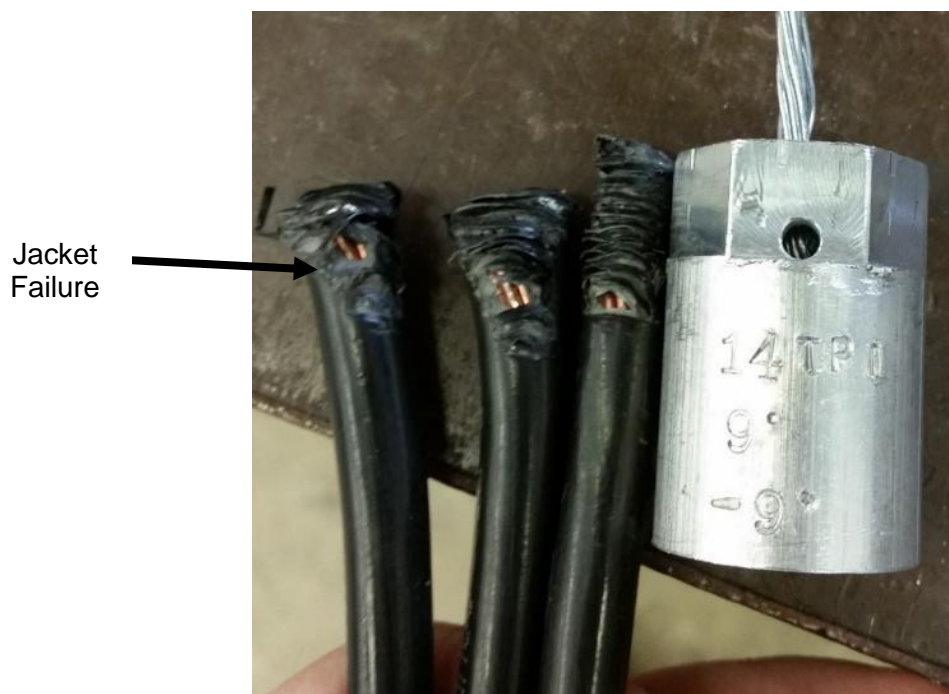


Figure 31: Tensile Failure of Jacket

Results

The holding strength of each of the eight grips were analyzed in a DOE setup. Grips were first tested on the tensile tester three times each, their holding strengths recorded in Table 4. In Table

5, the data was analyzed using DOE methods to find the average forces held (\bar{Y}) on each grip as well as the variance (S^2). For example, the average maximum tension \bar{Y} across all tests by Grip 3, which featured geometries **A-**, **B+**, and **C-**, was 145 pounds.

Interactions between **A**, **B**, and **C** were also organized into the table. For example, the interaction between taper **B** and angle **C** is recognized as column **BC**. The average holding strengths (each \bar{Y}) were summarized at the bottom of the table for each respective factor and interaction. For example, all grips with factor **A-** include holding strengths \bar{Y} of 256, 145, 216, and 119 pounds. The summation of these **A-** grips' strengths yields ΣY of 737 pounds, and therefore an average \bar{Y} of 184 pounds across all grips with factor **A-**. The average holding strength across all grips with factor **A+** is \bar{Y}_+ and has a value of 152 pounds. The overall effect is the difference of the two holding strengths \bar{Y}_+ and \bar{Y}_- which for factor **A** is -32.8 pounds. Therefore, the average difference in holding strength among any grip with factor **A+** and any grip with factor **A-** is 32.8 pounds. The effects of all factors and interactions are shown in the bar graph of Figure 32.

Table 4: Maximum Forces Held (all units in pounds force)

		A: Pitch			
		14 (-)		20 (+)	
		C: Tooth Angle		C: Tooth Angle	
		0 (-)	18 (+)	0 (-)	18 (+)
B: Taper	9 (-)	264	207	207	288
		207	240	198	226
		298	201	241	262
	15 (+)	166	128	73	66
		140	115	50	76
		130	115	62	69

Table 5: Means, Variations, and Effects of Maximum Forces (all units in pounds force)

Grip	A	B	C	AB	AC	BC	ABC	\bar{Y}	S^2
1	-	-	-	+	+	+	-	256	2114.3
2	+	-	-	-	-	+	+	215	514.3
3	-	+	-	-	+	-	+	145	345.3
4	+	+	-	+	-	-	-	62	132.3
5	-	-	+	+	-	-	+	216	441.0
6	+	-	+	-	+	-	-	259	969.3
7	-	+	+	-	-	+	-	119	56.3
8	+	+	+	+	+	+	+	70	26.3
ΣY_+	606	397	664	604	731	661	647		
ΣY_-	737	946	679	739	612	682	696		
\bar{Y}_+	152	99	166	151	183	165	162		
\bar{Y}_-	184	237	170	185	153	170	174		
Effect	-32.8	-137.4	-3.6	-33.6	29.6	-5.1	-12.3		
Abs. Effect	32.8	137.4	3.6	33.6	29.6	5.1	12.3		

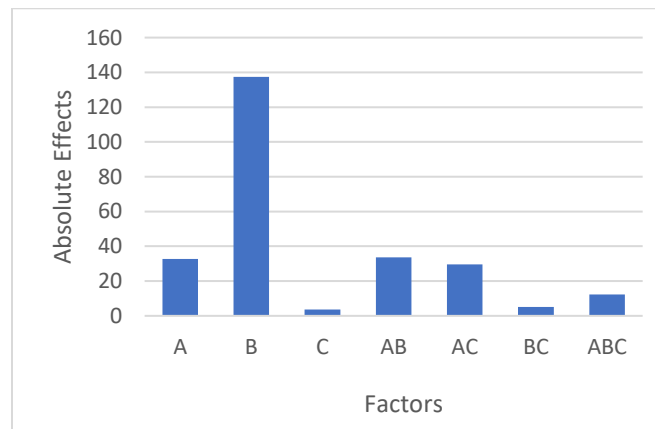


Figure 32: Effects on Pulling Strength

The effect of the taper **B** is so large, it is larger than the effects of **AB**, **BC**, and **ABC** combined. Therefore, it is safe to argue that **B** is indeed an important factor and may be screened from further testing in order to focus more on the effects of **A**, **C**, and their two-factor interaction. Working with limited time and budget was another important reason to screen **B** from further testing. The effect of **B** (-137.4lb) is negatively correlated with pulling strength, so **B-** was kept constant for the remainder of testing.

Testing continued on **A+**, **A-**, **C+**, and **C-**, and the results are shown in Table 6, with the results organized from least to greatest for each grip. The data was analyzed for outliers, but none were found.

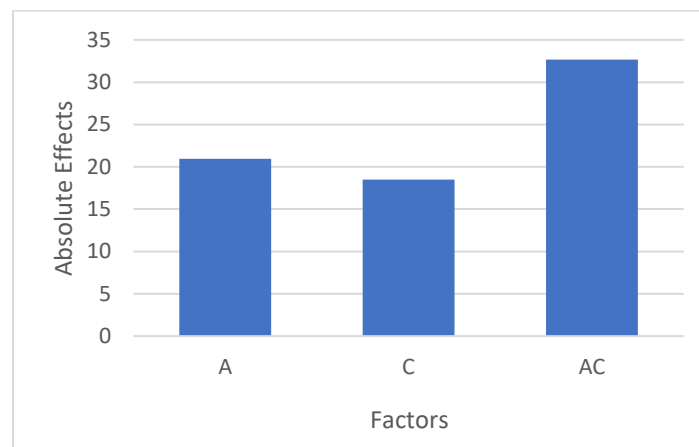
Similar procedures were conducted on the data as described previously (Table 7). The resulting effects for **A**, **C**, and **AC** were respectively -21.0, -18.5, and 32.7, as shown in Figure 33.

Table 6: Maximum Forces Held, (B-) Kept Constant (all units in pounds force)

		A: Pitch					
		14 TPI (-)			20 TPI (+)		
C:Tooth Angle	0 deg (-)	207	298	329	198	238	263
		264	302	334	207	241	277
		266	314	335	221	253	282
		296	317		234	258	
	18 deg (+)	201	239	270	208	262	288
		207	240	271	210	265	291
		227	263	283	226	277	291
		230	268		232	278	

Table 7: Means, Deviations, and Effects of Maximum Forces, (B-) Kept Constant (all units in pounds force)

Run	A	C	AC	\bar{Y}	S^2
1	-	-	+	297	1470
2	+	-	-	243	732
3	-	+	-	245	759
4	+	+	+	257	1040
ΣY_+	500	502	554		
ΣY_-	542	539	488		
\bar{Y}_+	250	251	277		
\bar{Y}_-	271	270	244		
Effect	-21.0	-18.5	32.7		
Abs. Effect	21.0	18.5	32.7		

**Figure 33: Effects on Pulling Strength, (B-) Kept Constant**

The average of all data across Table 7 (\bar{Y}) is 261lbs with an average standard deviation of 31.6lbs. The effective standard deviation is 9.5lbs, and the t-value was 2.02 for a confidence interval of 97.5%. Therefore, the data limits are +/- 19.3lbs so any effect greater in magnitude than 19.3lbs is considered significant. While **B-** is held constant, this leaves only **A** and **AC** as considerable effects. However, because the magnitude of the effect by **C** is only 4.1% below the data limit, its effects are predicted to still be relevant, and will still be included in the final regression equation.

Before determining the final regression equation, it should be noted that the effects of **AC** are being considered influential. It is hypothesized that the effects of **AC** are prominent because **A** and **C** will work together to determine the failure mode. That is to say, a coarse thread **A-** would normally improve gripping strength and tilted teeth **C-** would also increase gripping strength, but together they deeply sever the cable jacket and strip the jacket from the cable, as seen in Figure 31, resulting in an overall decrease in holding strength.

The final regression equation is determined to be:

$$\begin{aligned}\hat{Y} &= \bar{Y} + \frac{E(A)}{2A} + \frac{E(C)}{2C} + \frac{E(AC)}{2AC} \\ \hat{Y} &= 261 + \frac{-21.0}{2A} + \frac{-18.5}{2C} + \frac{32.7}{2AC} \\ \hat{Y} &= 261 - 10.5A - 9.3C + 16.4AC\end{aligned}$$

A taper **B** of 9.0 degrees was selected as it showed to result in the greatest holding strength, as well as being effective in creating a family of grips which capture an extensive range of effective diameters, explained further below. A pitch **A** of 14 TPI was also selected, along with a tooth angle **C** of 0 degrees, as this resulted in the highest grip strength.

Design Space for Exterior Geometry

A design space was constructed for the exterior of the proposed design to decide on internal and external dimensions which would allow the product to meet standards and geometric constraints.

Limitations to Fit around 90 Degree Bends

One requirement of the product is that it should easily navigate around 90 degree elbows, since 90 degrees is the greatest bend allowed in conduit and any bend less than 90 degrees will, by nature, be easier to navigate. Figure 34 introduces the basic geometry of the worst-case scenario, where a pulling grip is most likely to fail navigation through a conduit. Notice that its two outside corners, as well as the center of its inside surface, all make contact with the conduit. If the pulling grip is too long or too wide, it cannot be pulled around a 90 degree bend in the conduit.

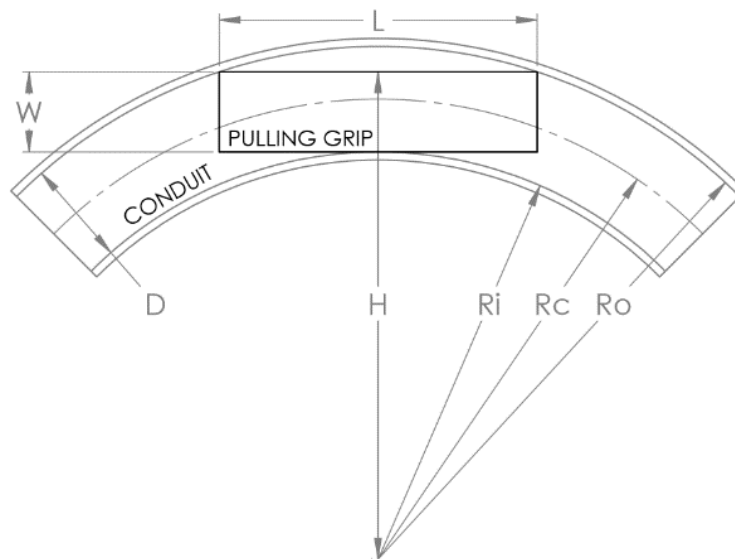
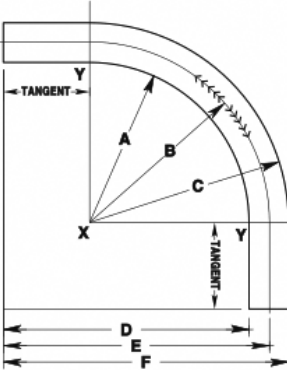


Figure 34: Conduit Geometry Used to Determine Maximum Length (L) and Maximum Width (W) to Navigate a 90 Degree Bend

To determine the length L and width W limitations of the pulling grip, Table 8 introduces all of the needed conduit dimensions, which are the radius of curvature R_c and the conduit internal diameter D .

Table 8: Conduit Geometries and Bend Radii (Source: Midsouth Wire & Cable)



Nom- inal Size (in.)	Diameters		Unbent Length (in.)	Radii		
	External (in.)	Internal (in.)		A (in.)	B (in.)	C (in.)
½	.840	.622	11½	3.83	4.25	4.67
¾	1.050	.824	12½	3.98	4.50	5.03
1	1.315	1.049	14½	5.09	5.75	6.41
1¼	1.660	1.380	17½	6.42	7.25	8.08
1½	1.900	1.610	19½	7.30	8.25	9.20
2	2.375	2.067	22½	8.31	9.50	10.69
2½	2.875	2.469	28	9.06	10.50	11.94
3	3.500	3.068	32	11.25	13.00	14.75
3½	4.000	3.548	39½	13.00	15.00	17.00
4	4.500	4.026	39½	13.75	16.00	18.25
5	5.563	5.047	59½	21.22	24.00	26.78
6	6.625	6.065	76	26.68	30.00	33.31

Note: Variables shown in this table are not representative of the rest of this paper ('A', 'B', 'C', 'D', 'E', 'F', 'Y')

The goal is to create a relationship between the length of the grip L and the width of the grip W so that the grip is sure to fit through the conduit. Equation (1) comes from the definition of R_i :

$$R_i = R_c - \frac{D}{2} \quad (1)$$

Equation (2) comes from the definition of R_o :

$$R_o = R_c + \frac{D}{2} \quad (2)$$

Equation (3) comes from the definition of H :

$$H = R_i + W \quad (3)$$

Equation (4) is a Pythagorean Theorem definition that comes from the right-triangle formed by the curvature origin, the center of the outermost wall of the grip, and either of the two outside corners of the grip:

$$H^2 + \left(\frac{L}{2}\right)^2 = R_o^2 \quad (4)$$

Equation (5) results from the substitution of equations (2) and (3) into equation (4):

$$(R_i + W)^2 + \frac{L^2}{4} = \left(R_c + \frac{D}{2}\right)^2 \quad (5)$$

Equation (6) combines and rearranges equation (5) with equation (1):

$$L = 2 \sqrt{\left(R_c + \frac{D}{2}\right)^2 - \left(R_c - \frac{D}{2} + W\right)^2} \quad (6)$$

Thus, equation (6) determines the length of the pulling grip **L** as a function of the conduit's radius of curvature **R_c**, the conduit's internal diameter **D**, and the external diameter of the grip **W**. A factor of safety **F** may then be added, to arrive at the following:

$$L = (1 - F) * 2 \sqrt{\left(R_c + \frac{D}{2}\right)^2 - \left(R_c - \frac{D}{2} + W\right)^2} \quad (7)$$

Where the factor of safety **F** is any percentage of extra confidence in the range of 0.0 to 1.0.

Minimum Grip Diameter

The second limitation comes as the grip's minimum allowable diameter **W** based on the internal geometry of the grip. The goal is to determine the minimum width **W** as a function of the minimum wall thickness **T_w**, the taper angle **B**, and the bore diameter **D_b**. The relevant geometry is shown in Figure 35.

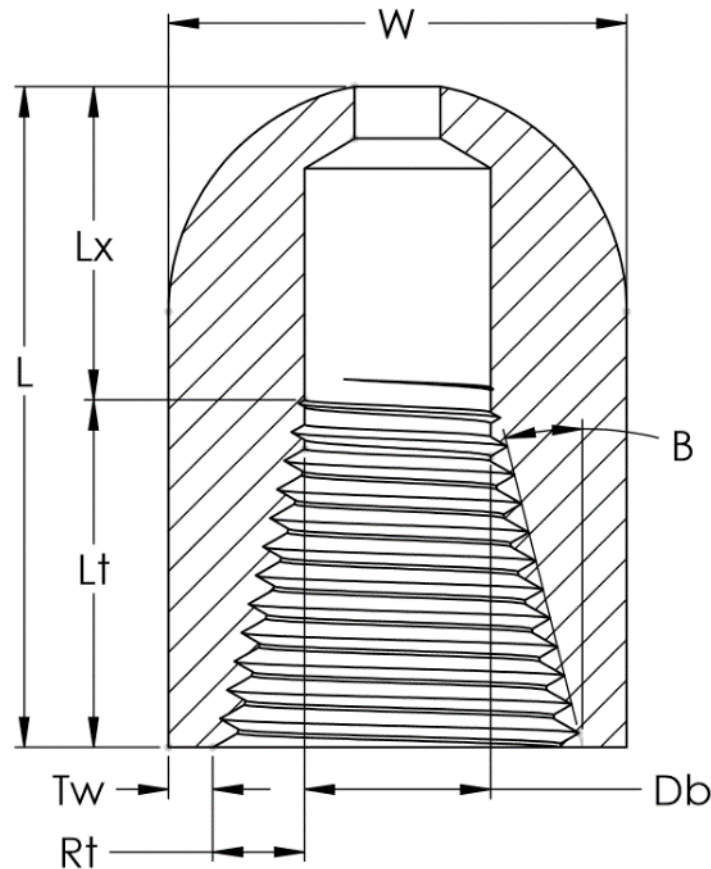


Figure 35: Grip Geometry to Determine Minimum Width (W)

The minimum diameter **W** is the summation of the minimum wall thickness **T_w**, the thread width **R_t**, and the bore diameter **D_b**:

$$W = 2T_w + 2R_t + D_b \quad (7)$$

The thread width R_t is a geometric relation between thread length L_t and the thread taper B :

$$R_t = L_t \tan(B) \quad (8)$$

Furthermore, the total length L is the summation of the effective thread length L_t and the excess space L_x . Therefore, it is determined that:

$$L_t = L - L_x \quad (9)$$

Substituting equations (8) and (9) into equation (7) yields:

$$W = 2T_w + 2(L - L_x)\tan(B) + D_b \quad (10)$$

Thus, Equation (10) determines the minimum external width W as a function of the internal geometries, mainly the minimum wall thickness T_w , the total length L , the length of the unthreaded portion L_x , the taper B , and the bore diameter D_b .

Minimum Machinable Length

The third geometric limitation is the minimum machinable length. Generally, the larger the workpiece diameter, the more of the workpiece should be held in the chuck. There is no hard rule for how much to hold in the chuck (see “Email to Mike Fulk”). Therefore, it was given a general rule of thumb, determined through the practical use of the machines, that the minimum chucked length should be at least half of the diameter being chucked.

Minimum Ergonomic Length

Lastly, there is the minimum length based on ergonomics. It was determined through usage that the grip is uncomfortable to use if it is less than half the width of the palm. The average adult male hand has a width of approximately 3.30” (“Average Hand”), so the minimum ergonomic length was determined to be approximately 1.65”.

Final Design Choices

During a discussion with customers (Meeting with Sycamore Engineering, page 59), it was discovered that the larger grips, mainly the 3.00”, 2.50”, and 2.00”, are less practical as the maximum tension grows exponentially with the nominal diameter of the conduit. It was suggested that this product be tailored towards small pulls, around the 0.50”, 0.75”, 1.00”, 1.25”, and 1.50” conduit range, and that the larger diameters be discarded.

The four boundaries were then plotted on five design spaces – one for each nominal diameter of conduit. A point was then selected which satisfied all limitations of the design space. A point was chosen for each design space except for the 0.50-inch and 0.75-inch conduit grips, as they did not have viable design spaces. Figure 36 through Figure 40 shows the design spaces for each of the eight nominal diameters of conduit, given a factor of safety F of 0.07 (i.e. 7%).

A width W and length L were selected on each design space along the 90 degree bend limit. This was to ensure maximum versatility of the grips; if the selected point was not along the 90 degree bend limit, that is to say if it was towards the left, the grip would have a smaller exterior diameter and consequently a smaller internal diameter, limiting its ability to hold larger diameters of cable bundles.

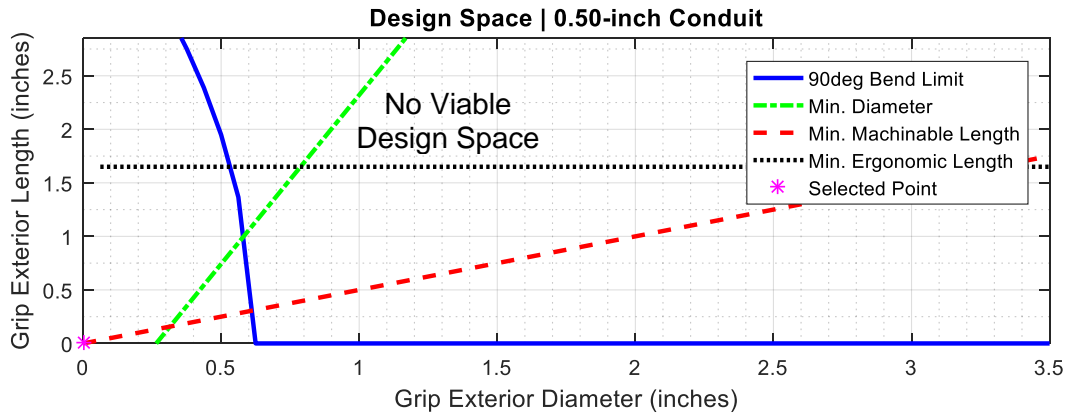


Figure 36: Design Space for 0.50" - No Selected Point

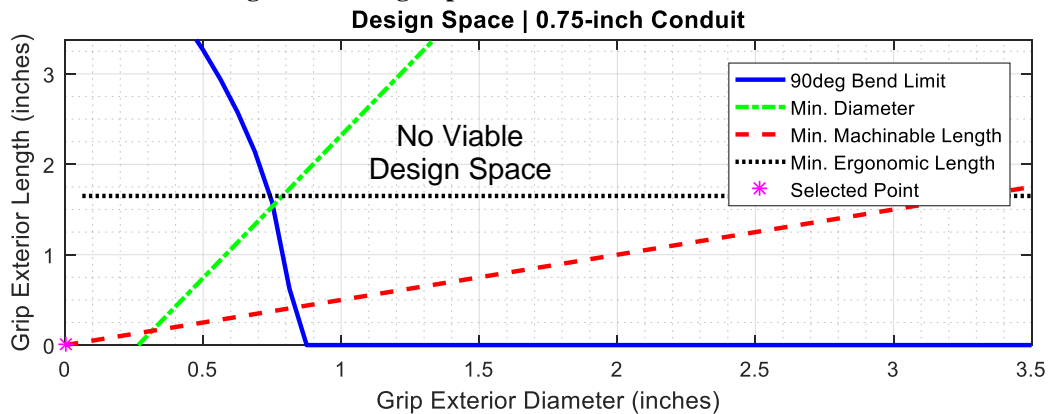


Figure 37: Design Space for 0.75" - No Selected Point

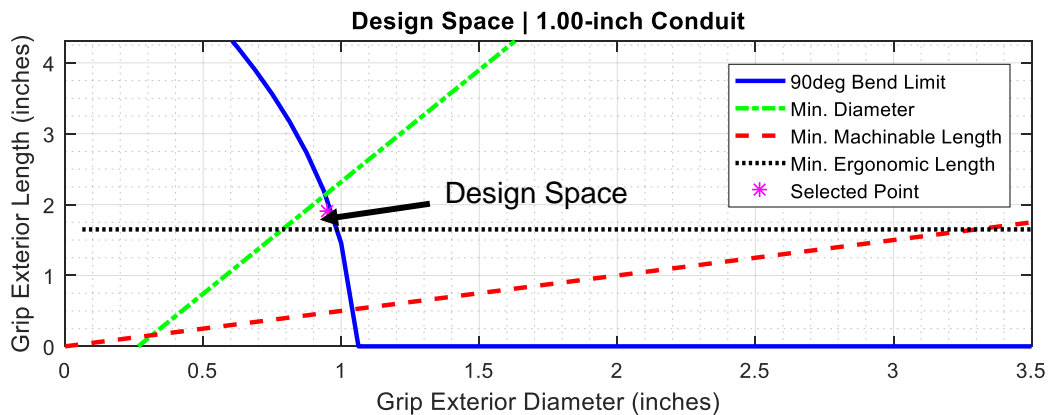


Figure 38: Design Space for 1.00" - Diameter 0.95", Height 1.90"

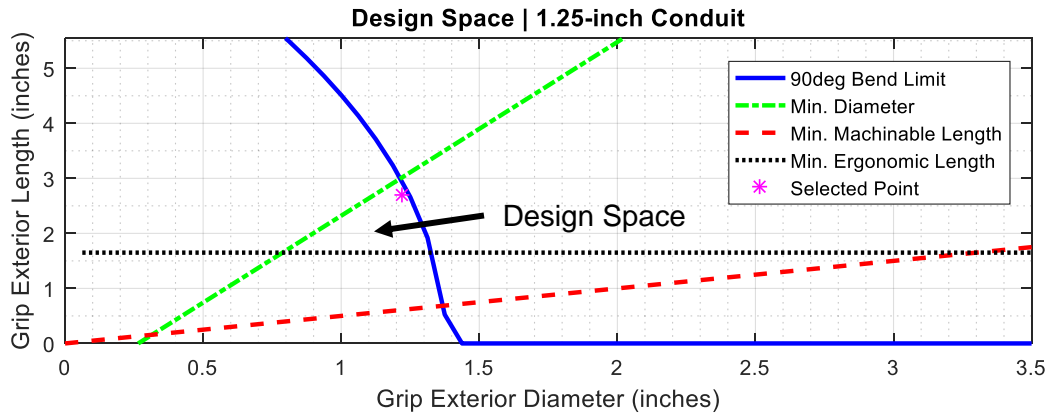


Figure 39: Design Space for 1.25" - Diameter 1.22", Height 2.70"

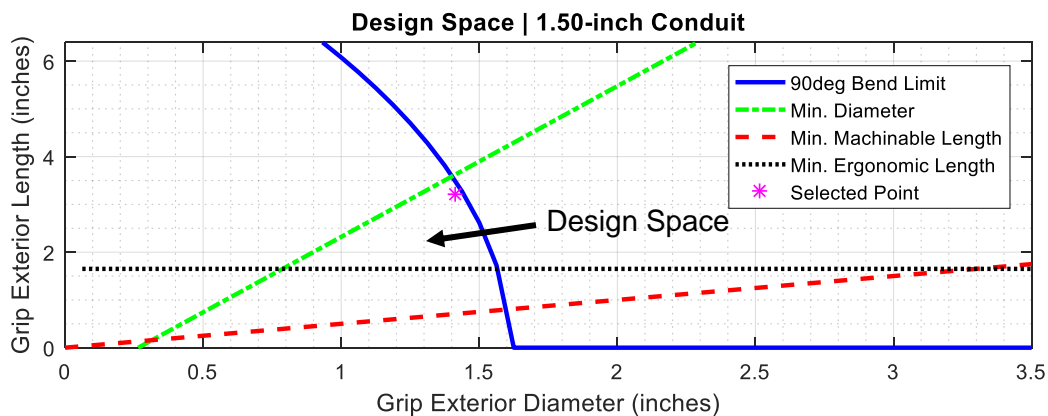


Figure 40: Design Space for 1.50" - Diameter 1.41", Height 3.20"

It just so happened that the minimum machinable length restriction played little to no role in choosing a design space, since the minimum ergonomic length was always more restrictive than the minimum machinable length requirement. The selected width **W** and length **L** for each pulling grip are summarized in Table 9.

Table 9: Selected Widths (**W**) and Lengths (**L**) of Grips Associated With Each Size of Conduit

Conduit Nominal Diameter	Conduit Internal Diameter	Pulling Grip Width (W)	Pulling Grip Length (L)
0.50"	0.62"	NA	NA
0.75"	0.82"	NA	NA
1.00"	1.05"	0.95"	1.90"
1.25"	1.38"	1.22"	2.70"
1.50"	1.61"	1.41"	3.20"

Given the width **W** and length **L** of each grip, it is now possible to determine the range of cable bundle diameters which may be held by the grips. All grips are still assumed to have an internal taper **B** of 9.0 degrees. A cable bundle is measured by its effective diameter **D_{eff}**, which is the

diameter that circumscribes an optimally packed bundle of cables. For visual reference, a series of optimally packed cable bundles are visible in Figure 41.

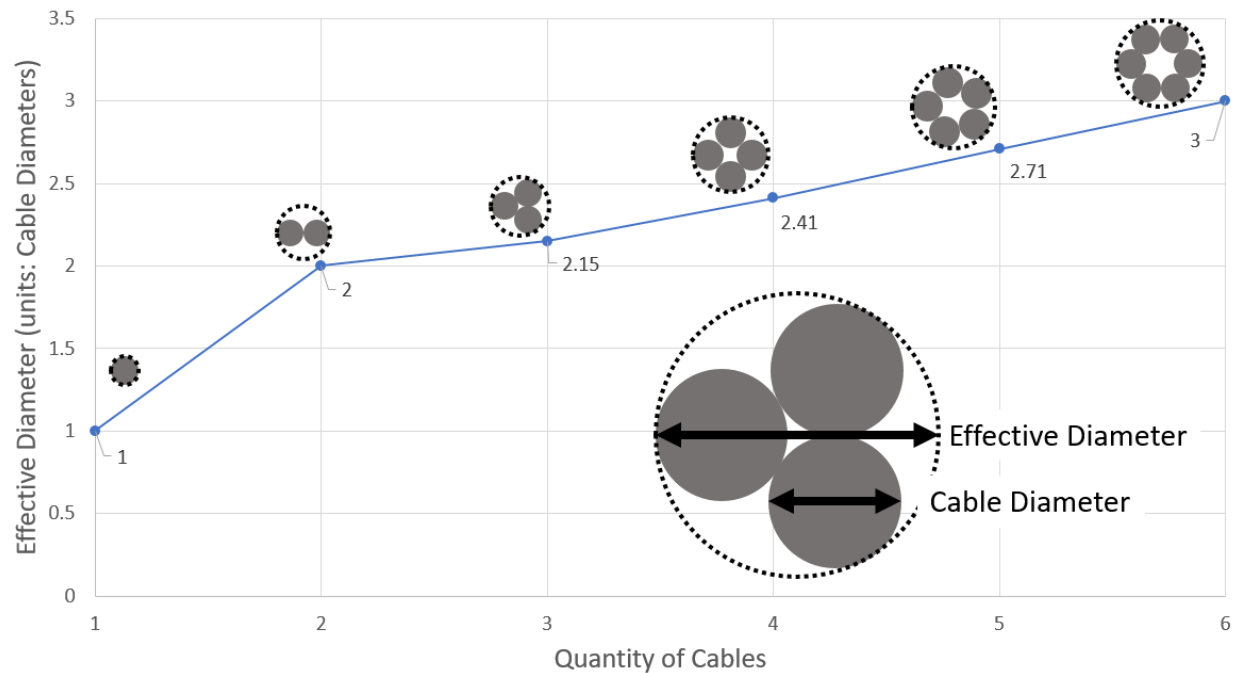


Figure 41: Rate of Change of Effective Diameter as Cable Quantity Increases

The relationship between grip exterior diameter W and the grip's minimum wall thickness T_w was previously explained in equation (7) and Figure 35. Now, let the thread maximum diameter D_m be represented as:

$$D_m = 2R_t + D_b \quad (11)$$

Then, from equation (7) and equation (11), it can be determined that the thread maximum diameter D_m is:

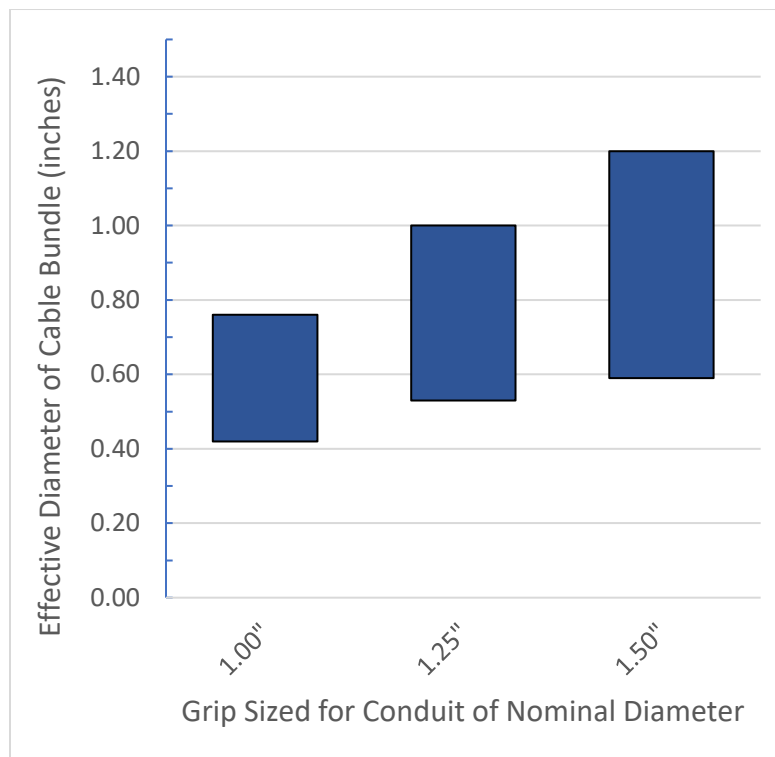
$$D_m = W - 2T_w \quad (12)$$

Therefore, the maximum thread diameter D_m may be found. The minimum thread diameter D_b is already known, recognized also as the bore diameter. The range of effective diameters are summarized in Table 10, with a visual representation in Figure 42.

The span of compatible effective diameters, approximately 0.42" to 1.20", nearly satisfies the product requirement of being able to grip between 0.25" to 1.25" cable bundles. The inclusion of a 0.5" and 0.75" grip is likely to fulfill the product requirement, therefore this warrants future investigation into the geometry of the product.

Table 10: Range of Effective Diameters

Conduit Nominal Diameter	Grip Minimum Thread Diameter (D_b)	Grip Maximum Thread Diameter (D_m)
0.50"	NA	NA
0.75"	NA	NA
1.00"	0.42"	0.76"
1.25"	0.53"	1.00"
1.50"	0.59"	1.20"

**Figure 42: Range of Effective Diameters**

The family of grips were then tested in the following chapter to ensure the chosen design met product requirements, including the ability to navigate 90 degree bends in conduit, hold a tensile load, and be reused for multiple pulls.

Lab Testing and Results

After the product design was completed, a kit of the three largest diameter grips was constructed and tested in the Rose-Hulman Machine Shop to ensure maximum tensile strengths were sufficient enough to meet the product requirements. They were also tested to ensure they successfully navigated bends in conduit.

The kit was comprised of a 1", 1.25", and 1.5" grip, manufactured to the design described in the previous sections (Figure 43). The grips were manufactured from 6061 aluminum.



Figure 43: Lab Tested Grips

The grips were tested for pull-out strength in the same methods and using the same equipment as described in previous chapters. Grips were attached to cables using a torque of 35 inch-pounds. Since all the grips have the same internal geometry they should all theoretically have similar pullout strengths. Thus, the pullout strength was hypothesized to be a function of the number of cables held, since more cables would allow more surface area to be threaded and thus increase holding strength. Therefore, the grips were tested with some variance in the quantity of cables held; 3AWG cable was held in bundles of quantity two, three, and four (Table 11).

Table 11: Lab Tested Pullout Strengths (units: pounds)

1" Grip		1.25" Grip
2x 3AWG	3x 3AWG	4x 3AWG
239	281	351
204	292	340
229	294	267 ¹
226	286	*
228	257	*
231	280	*

¹ Cable became difficult to insert evenly, and threads failed to engage with all four cables. Data collection became difficult, and requires further investigation.

It was discovered, as cable quantity moved up, that the grip would fail to engage with all cables evenly. This would lead to a premature failure, because when a cable would pull out from the grip the other cables would decompress and fill the void left by the escaped cable. This lead to a decrease in the thread engagement, and thus a 20-30% loss in holding strength. This issue warrants further investigation, however using the data collected, Figure 44 was created.

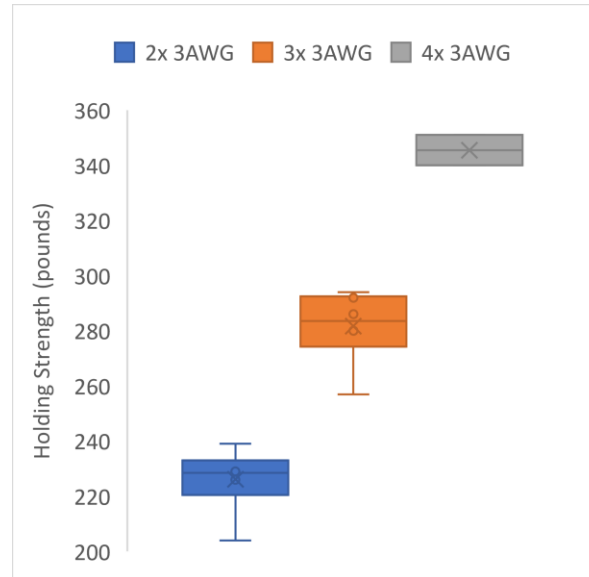


Figure 44: Cable Bundle Max Strengths

This plot shows that the proposed design will indeed hold at least 250 pounds of tension, as specified in the product requirements. However, this success may be misleading, as it is evident that the pullout strength becomes a factor of the size and quantity of cables held. Therefore, the pullout strength for smaller/fewer cables may be significantly less. Thus, it may be hypothesized that holding strength is better compared against the maximum applicable tension, which is derived as a factor of the cable cross-sectional area (Table 12) and allowable material stress (Table 13). However, maximum tension found in this method shows that 3AWG cable can handle up to 421 pounds of tension per cable, which does not provide validation that the grip will handle the maximum expected load.

Table 12: Cross Sectional Area of Cable (Source: www.southwire.com)

<u>AWG</u>	<u>cmil</u>
12	6,530
10	10,380
8	16,510
6	26,240
4	41,740
3	52,620
2	66,360
1	83,690
1/0	105,600
2/0	133,100
3/0	167,800
4/0	211,600

Table 13: Maximum Allowable Stress of Materials (Source: www.southwire.com)

Cable Type	Material	Temper	lbs/cmil
All	Copper	Soft	0.008
Power	Aluminum	Hard	0.008
Power	Aluminum	3/4 Hard	0.006
Power	Aluminum	AA-8000	0.006
URD	Aluminum	1/2 Hard	0.003
Solid	Aluminum	Soft	0.002

Therefore, while the grips will handle the loads specified in the product requirements, the true performance of the grips will depend on other factors such as quantity of cables, cable material, jacket material, and the potential for premature failure due to unengaged threads, that will warrant future investigation.

Conclusions and Future Work

In the course of this integrated project, the viability of a business venture in manufacturing and selling a pulling grip was evaluated. It was found that a problem existed in the current methods of preparing cable for installation – that it was time consuming and thus costly to the contractor. This problem was validated through conversations with customers, who stated a willingness to pay for a solution which decreased the time required for pull setup. It was also shown that this demand especially existed for low-tension pulls, which make up the bulk of on-site pulls.

Market research revealed the shortcomings of competitors' products, and where a new product might improve on existing designs. It was shown that there has been little market innovation in the years, and that large competitors such as Greenlee and SouthWire have failed to supply new product designs to the ever-expanding electrical industry.

An intellectual property search revealed the same designs used by Greenlee and SouthWire. The search also revealed a previous patent application similar in design to the proposed product. This previous patent has fallen into abandonment since its filing, therefore it will not hinder the progress of the proposed design. However, this also prevents intellectual property claims on the proposed design since it is now considered within the public domain. Without novelty in the design, a patent is unlikely to be granted, and therefore it would be worthwhile to take a closer look at the possibility of adding novelty to the design.

Should the project then proceed, marketing will be done initially through on-site demonstrations and visits to contracting firms. Later, marketing will be conducted in the form of advertisements placed in strategic channels, such as industry magazines and conventions. A landing page will also be created for self-promotion of the product, and all channels will direct purchasers to distributors, who will seek out the product themselves as demand increased among their customers. A business model canvas was used to summarize the initial strategy to enter the market. Development of a full business plan is beyond the scope of this project.

Customers were then solicited for product requirements. Through general knowledge held by the author, as well as insight provided by customers, a total of eighteen quantifiable metrics were created to measure the success of the product design. The overall success of the product depends also on product marketing, customer satisfaction, and securing the design from competitors.

Prototypes allowed for the rapid evolution of the product, phasing out design hindrances and quickly evolving manufacturing methods to create an easily reproducible design. The design was then refined by creating design spaces based on product requirements.

Based on constraints created by the design spaces, a kit of three grips was manufactured and tested for holding strengths. It was found that the maximum pullout tension was a factor of the quantity and diameter of cables inserted, and therefore hard to predict. However, the design has shown that it is capable of withstanding the tensile load requested in the product requirements. It was also found that there may be an issue with the grip not fully engaging all cables in a bundle, resulting in failure.

In conclusion, the product seems to resound successfully with customers especially when presented with a live demonstration of the product. It is predicted that the product has a place within the electrical contracting industry, especially in favor of aiding with low-tension, shorter

pulls. However, for the product to be successful, two main concerns must be addressed in the future.

First, the design should be made so that the cables are more likely to equally engage with the threads of the grip, thereby reducing the chance of early failure due to a single cable slipping out of the bundle. This is especially important as it was described by a customer that the product is only going to sell if it works each and every time. It is worth investigating if the material selected for the grip is a factor in influencing the full engagement of the threads; for example, switching the aluminum for a high-hardness steel may allow the grip to thread into the copper interior, holding the copper as well as the cable jacket.

Second, should the product become successful, competitors are quick to capitalize on any market where there is demand. This is obvious when looking at recent fads such as the demand for Fidget Spinners. Therefore, something needs to be in place which protects the design from being copied by competitors, whether it is novelty that leads to intellectual property rights, or manufacturing secrets that hinder competitors from mimicking the design. For the security of market share, this issue warrants future investigation.

Appendix A: Bibliography and Sources

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Midsouth Wire & Cable. “45 Degree Conduit Elbow.” *Midsouth Wire & Cable*, <https://inetparts.com/45-degree-conduit-elbow/>

NECA & the Electrical Contracting Industry. NECA, www.necanet.org/about-us/overview/neca-the-electrical-contracting-industry.

Appendix B: Recognition

Zachariah Chambers	Thank you for your knowledge of entrepreneurial ventures and support in reading this paper.
Tyler Dinkel	Thank you for your time in meetings to provide product feedback.
Mike Fagg	Thank you for the time taken to demonstrate on-site pulls.
Mike Fulk	Thank you for your cheerful attitude, support, and knowledge of machinery and general insight.
Kevin Handling	Thank you for the time taken to demonstrate on-site pulls.
Eric Hayes	Thank you for your support in connecting the author to those at Sycamore Engineering and Garmon Construction.
Thomas James	Thank you for your support in being an academic advisor to this paper, your well of entrepreneurial knowledge and your motivational support.
Terry Schumacher	Thank you for your knowledge in marketing, segmentation, and new products.
Mom & Dad	Thank you for the support throughout the years and the drive you've instilled in me.

Appendix C: Contact Information

Sycamore Engineering | 812.232.0968

Tyler Dinkel |

Jones Fabrication and Machining | 812.446.2237

Jeff Kackley | jeff@jonesfabmachine.com

Explained, "JFM does not have the equipment to manufacture this part."

Dalex | 812.232.7081

dalex@mar.rr.com

No response to emails.

Indiana State University | 812.237.7677

Mark Clauss

Called and left voice mail. Twice. Waiting for response.

Britt Tool Inc. | 812.446.0503 ext. 106

Mike Wyrum | mike@brittaero.com

Explained, "We just got a lot of work. Try contacting Master Machine."

Master Machine | 812.232.6583

Randy Flowers | mastermachinc@aol.com

Sent email, waiting for response about capability of producing. Willing to work for free? Almost too eager to work?

D&D Automation Inc. | 812.299.1045

David | david@ddautomation.com

\$41 per part or less, depending on difficulty of the cut.

Parsons Custom Machining Inc. | 812.877.2700

Explained, "We sold everything and retired."

Specialty CNC Inc. | 812.825.7982

Explained, "Overbooked for next 6 months."

AP Machine and Tool Inc. | 812.232.4939

Mark | mark@apmachineandtool.com

Explained, "I believe we can do this. We'll have a quote done over the weekend." Up to \$80 per piece 8128784816 is his cell number. Stop by Monday with part in hand to get final number.

Kihm Metal | 812.442.7468

Tim Callahan | tcallahan@kihmmetaltech.com

Explained, "We do not have a good way to cut these threads."

Exactifab | 812.420.2723

Can only get busy tone when dialing.

Checkered Past Racing Products | 317.852.6978

Justin | checkeredpast@sbcglobal.net

Around \$35 per part

CNC Machine Co. | 317.835.4575

Explained, "We are a production shop."

Oliver Machine and Tool Corporation | 765.349.2271

Eric | olivermachine@att.net

Explained, "We are unable to manufacture this part."

Northside Machine Co. | 812.648.2636

Mike | northsidemachine.com

Can't do the thread form, all CNCs are in use.

Appendix D: Recorded Conversations

Email to Mike Fulk

Sunday, October 15, 2017

Subject: Minimum Workpiece Depth in Lathe

Hey Mike,

I'm crunching some numbers on my report and I'm writing a section about the minimum length of the pulling grip. To determine this, I wanted to inquire if you know, in general, a rule of thumb for the required depth of the workpiece?

For example, if the workpiece is 1" in diameter (and, let's say, 5" in length and not supported at the other end), how far should the workpiece be inserted into a collet at minimum, would you say? This number isn't critical to any process, but soliciting an expert's opinion sounds better than me making up a number.

Thanks,

Tyler

Monday, October 16, 2017

Tyler,

When I'm asked about the maximum length to let stick out of the chuck without live center/tailstock support, I tell folks 3 times the diameter of what is being turned. That statement does not address how much is actually in the chuck ,,,,a question you are asking. I seems to me you could put the part in the collet at the mid point of the part and be safe from it coming out of the collet (which is much better than a 3 jaw chuck).

I do not have an number for you in this case. You will have to match your depth of cut to what you tooling will hold.

Mike

Observation of Cable Pull

Thursday, March 30, 2017

Attendees:

- *Tyler Miller, RHIT*
- *Thomas James, RHIT*
- *Kevin Handling, Garmong*
- *Mike Fagg, Sycamore Engineering*
- *Tyler Dinkel, Sycamore Engineering*
- *Jim, Garmong*

Summary

At approximately 8:00am on Thursday, March 30, 2017, Dr. Thomas James (TJ) and I met with Kevin Handling (KH) of Garmong Construction Services, in the occasion of observing a cable pull on-site at the Rose-Hulman Institute of Technology during the reconstruction of its Hulman Union. KH was the primary contact for this meeting.

Introductions

KH was the site manager and introduced us to Mike Fagg (MF), a foreman for Sycamore Engineering. MF explains that most pulls are done by hand but for big pulls they use a Super Tugger (Greenlee), a Versiboom (Greenlee), and/or a third model. MF explains the use of "Super Slick wire," known industrially as "Southwire SIMpull THHN copper cable." It was ordered through distributor Kirby Risk. MF praises the super slick wire because it has saved time and money by removing the need of a worker to apply messy lubricant to the wire before it enters conduit.

The Pull

The preparation of wires for the pull was videotaped and stored as a digital file. For preparation, worker Jim, using a standard utility knife, stripped the 3 cables of size AWG 3 and 1 cable of size AWG 8 to expose approximately 8" of copper on each. Then, using the tip of the knife, separated the copper strands and unwound them to create two distinct branches of the copper. To reduce bulk, about half of the strands on the larger cables were trimmed away but two distinct legs were still retained. Next, MF held stable a "fishing tape" and all 8 legs of the cable were inserted into an eye hole of fishing tape, which had already been fed through the conduit. The legs were twisted down around themselves, then crimped with pliers to reduce bulk, and finally taped in place with electrical tape.

Alternatively, for approximately \$50 a pre-attached pulling head is also available when ordering the cable. I'm not sure if this is exclusive to Southwire SimPull.

The 175' pull was completed by a worker on the other end of the conduit manually pulling the fishing cable through, which brought the cables along with it. There was approximately 5' of extra cable, each, at the end of the pull. This cable was worth ~\$5/ft/cable.

Alternative Methods

Jim mentioned that cable socks (chinese finger traps, Kellem(?) grips, etc.) had slipped off many times in his past experiences. To combat this, sometimes the cable is drilled and bailing wire fed through the cable to promote adhesion of the cable sock. Tie wires are also sometimes used.

For larger pulls, MF mentions that duct tape is used instead of electrical tape to make a head. It is wrapped around the cable, sticky side out, then again around the cable, sticky side in. This prevents the adhesion of residue to the cable and makes for quick removal with a utility knife afterward.

It may be assumed that pulling by hand is faster than pulling by tugger, because setup by hand is less and the tugger would have to be mounted to the floor.

Junction Boxes

Junction boxes are set in-between runs of conduit to act as a “checkpoint” for a pull. Since a pull is only allowed 360 degrees of bends in the conduit (due to electrical codes), cable is often pulled to a junction box, then fed back into the box to continue down another path of conduit.

Price Modeling

Sycamore Engineering Senior Project Manager, Tyler Dinkel (TD), also briefly attended the pull. He points out that it took 2-3 guys around 4-5 minutes just to tape up the pulling head. Given the amount of money and time used, TD would pay up to \$100 for a quicker one-man solution.

Need 1

A need described by MF is the deletion of the cable fishing step. He describes “If you could make a little crawler that would pull the rope through the conduit, that would save us so much time.” MF is unsatisfied with having to feed fishing tape through, then rope, then cable. Currently, fishing tape is attached to a mouse and vacuumed through conduit.

Need 2

Another need described by MF is a faster processing time for determining the length of conduit. When conduit is installed, MF currently passes a string through, removes the string, measures the string, and orders cable to length with a 10%-20% fudge factor in length. This fudge factor results in waste, but is less costly than being undersized. Software such as Building Information Management (BIM) is great to predetermine lengths, however even it is not entirely accurate.

Meeting with Sycamore Engineering

Friday, December 22, 2017

Attendees:

- *Tyler Miller, RHIT*
- *Tyler Dinkel, Sycamore Engineering, Field Project Manager*
- *Christopher Loveall, Sycamore Engineering, Chief Electrician*
- *Rocky Mansard, Sycamore Engineering, Manager | Field Services Tech Support*

[after signing NDAs]

Miller: Alright, thank you very much, guys. I'd like to start by looking at the problem we will be addressing. So, here is a video that was taken on site last time I met with Mr. Dinkel. This is the current way people prepare cable for pulling through conduit. Here, we see this gentleman preparing cable by cutting it to length, then using a utility knife to strip the cable. And notice, as he's doing this, he's standing awkwardly with his knees crossed and about to fall over onto this knife.

Loveall: At this point I'm just really happy that he's using the knife away from his body.

[laughter]

Dinkel: And that he's wearing his cut-proof gloves.

Miller: Are those very common? Do you guys wear those all the time?

Dinkel: Absolutely, a hundred percent, especially in this application.

Loveall: The average hand injury is about \$2000.

Dinkel: The majority of our injuries occur on hands and fingers.

Loveall: Are we making a long run here? I notice they're going through a lot of trouble here.

Miller: I believe when I asked them, they said this was 250 feet.

Loveall: Okay.

Miller: So there he's untangled the copper cable, and has wrapped it through the fish-eye. So he's making the head. He's wrapped it through, gonna wrap it back around - he's stripped all three or four cables, wrapped all three or four cables, he's gonna tape it up here in a second. Now, notice there's a second gentleman helping him here in this part. Is that very common? Is there usually a second person helping?

Loveall: Yes, because usually when you're setting up to pull wire you've got two or three people there. Now, theoretically he could've taken the time to tie it off to a metal stud, instead of having him hold it.

Miller: So he'd still have to take the time to tie it off?

Loveall: Right, he would've tied it off to a metal stud or something that was stable so he could've done the work instead of Mike holding it.

Miller: Okay. So this was a shortened video, about 2 minutes, the actual process took about 8 minutes in length. And so if you combine two people you're looking at about 16 man-minutes of work. And so the process, how I'd like to simplify it, is getting rid of stripping the cable jacket, getting rid of tying it around the fish-eye, making the head, and everything. Which comes to this product that I've been working on, which is essentially a newer version of a pulling grip. So the idea here is that you can take any size of cable bundle and all you would have to do is jam it in, and twist it on. And you guys can give it a try if you'd like, I have some extra cables here.

Loveall: So you're relying on the insulation, not the copper?

Miller: Right, so we're relying on the insulation to hold onto it, and the idea is once you twist it on, you would have a wrench that you could use to finish tightening it. And getting it slightly more than hand tight, we've found in lab tests that it will hold slightly more than 300 pounds.

Loveall: Which, for hand pulling, would be sufficient. With the machine, we quickly exceed that.

Miller: Right, so that's one of the things I wanted to look at, is how often you guys do hand pulls versus a machine pull.

Loveall: Well, it depends on the length, the size, and the application. So, the diameter of this is very well suited for this size of conduit (Loveall is referencing the 1" grip in relation to the 1" conduit). But obviously that is not, it won't even go in there (Loveall is referencing the 1.5" grip in relation to the 1" conduit). And you have to be very careful, because nothing is made in the United States and nothing is made with our standards anymore. So, the diameter of this conduit is not continuous. Sometimes it changes, it fluctuates, it's not perfect all the time.

Miller: So the conduit may actually have different internal diameters.

Loveall: Correct. What we're worried about is getting those three wires in there and that's well under the 80% fill we have to normally calculate for. So, yeah I don't see why it wouldn't work, so long as it can pull through the pipe.

Miller: So, you say that there are fluctuating diameters inside the pipe, so is that from company-to-company, are those-

Loveall: Manufacturer to manufacturer. PVC conduit, have you seen that? We often field bend that with heat, it'll distort. When hand-bending conduit, depending on which bender we use, that determines the radius. And it could distort a little bit. Electricians deal with ID, we don't care what the OD is of conduit. The OD of that is 1 3/8", the ID of that is 1". So as long as you stay within that 1" and it'll smoothly go around the radius of that conduit, that would be my only concern.

Miller: Okay, so what I've been looking at is a kit, so here we have a 1", 1 1/4", 1 1/2", and 2". So, each of those would fit into the different conduit sizes. So for example, this grip, which is an older model but still demonstrates the point, it works with 1" conduit and so like you said, it should fit around the corner.

[Miller demonstrates the grip navigating the 90 degree conduit bend]

Miller: And so the idea would be that we would make sure each of these did the same, fitting around corners. And the maximum bend that you guys have, would you ever go past a 90 degree bend?

Loveall: It would be unusual. Generally the National Electric Code dictates that we are allowed up to 360 degrees of bends in a run of conduit before a junction box, the only exception is if we were installing level sensors.

Miller: So assuming we got this all set up and going, do you believe 300 pounds would be sufficient for the hand pulls?

Loveall: Oh, yes. Now, when you get into 2", no, because that is a 3/0 copper or 4/0 copper and that would be a mechanical pulling device - a tugger, which gets up to 10,000 pounds. What I would do is go back to your wire manufacturers, like SouthWire, they will tell you the maximum tension that wire can be pulled at.

[Rocky Mansard enters]

Dinkel: This is Rocky Mansard, he's one of our foremen actually.

Miller: Good to meet you, Rocky.

Dinkel: Hey Rocky, we need you to sign an NDA.

Loveall: He's got a good idea and he don't want you to pimp it.

[Mansard signs NDA while Loveall finishes pulling up a webpage]

Loveall: The electrical industry is always evolving. There's thousands of people with good ideas and plans and everything else, and there's a company called Rack-A-Tiers, and I've had a couple ideas myself and I've dealt with the gentleman and he's interesting to talk to. He works with people with ideas. SouthWire, they've got the Simpull which is the pre-lubricated wire, but they have a calculator that will tell you how much tension a wire pull is going to take. It's on the SouthWire webpage, it's free, and I use this alot for bigger pulls because they want to know I'm not going to damage that cable. That'll tell you pulling tensions and everything, based on your lubrication, fittings, bends, conduit size, so on.

Dinkel: On the mechanical tuggers we have, they actually have a tension gauge that'll actually tell you real-time what your tension is and record the data, so that you can show at the end of the day that it did not exceed some limit. The wire that shows up on our doorstep will actually have a tension strength printed on it.

Loveall: One thing that I would suggest, Rack-A-Tiers, I actually called him - fascinating individual. He actually has his thumb on the electrical industry. And I had an idea I thought was marketable, and he said there's something like, forgive me I won't be accurate, 150,000 licensed practicing electricians in the United States. He said 25,000 of them are authorized to buy materials and tools. There's 7,000 supply houses. So 25,000 electricians go to 7,000 supply houses in the United States and he said, of them I can get you in about 2,000 supply houses. He said, your product is going to be a \$50 item, he said, if I do all the patent work and I do all this and get it all set up, I'm gonna charge you 90% and I'm gonna give you 10%. He said, you're gonna sell 150 of them and we're gonna make \$50,000, and you're gonna get \$5,000.

[all laugh]

Loveall: But he knew a lot about it and he knew what would sell and what wouldn't sell. It's what he does. And there's several of these companies out there. They show up at trade shows. Just go up to them and see what they say. You don't have to reveal anything, tell them you've got a grip for wire and that you've figured out a way to attach wire to a rope. That's all you need to say.

Miller: Okay, sure. Rocky, to catch you up, what we've been looking at is a process to remove stripping the cable and making a head and everything. We're trying to simplify that and made it a little bit quicker.

[Miller re-explains how the grip is used]

Mansard: Cool. And... useful? (directed towards Loveall)

Loveall: Mm-hm. See, this is what they've been trying to use and its been selling. It's called the Snatch Strap. Instead, you just fold it over and hook it. They don't work.

Miller: What's wrong with them?

Loveall: The hook comes off, they break, they just don't work. And see, they don't want you to strip the cable. They say you just grip it through that little triangle.

Dinkel: There are other pulling grips not identical to this but similar. They use a method like a chinese finger cuff. Made by 3M. They slide over the bundle and they have a really good tension grip. We use those on big pulls. You just slide it on, duct tape it, and it'll take three minutes to set up.

Miller: Okay. You don't have a problem with that slipping off?

Dinkel: No.

Mansard: That's unique by design, I suppose. The harder you pull, the tighter it gets.

Dinkel: Something else, in larger cable sections, we'll actually order the cable with the head already installed on the cable so we don't have to do it ourselves.

Miller: Who offers that?

Dinkel: Manufacturers. They cost us \$300 or \$400 but we pay for it because it saves us a lot of time. Sometimes they just do it for free.

Loveall: As long as you can get the guys to install it correctly, and it holds, you're good. Electricians are creatures of habit and they don't like to change easily, and if they buy your product and it fails once then they'll throw it in the box and never use it again. But if it works, then everybody wants it.

Dinkel: We live by an acronym: KISS. Keep It Simple and Stupid.

Loveall: And you're right, with your sales pitch. Right now our guys cost us right at \$1.07 a minute. So, right there you watched \$2.14 and you said your movie was two minutes, that cost Tyler almost \$5.00. So anything you can shave off that is money in his pocket.

Miller: So if we can shave that down to a minute to screw this on and a minute to screw this off again, and now you've got a reusable one, you don't have to crimp it on then throw it away or waste it-

Dinkel: The one thing you have to change though with this design is being able to not have any resistance when it's going through the pipe. You have to have some type of, uh, well you'd have to make it out of metal.

Loveall: Maybe make it out of nylon or something that lets it slip easier.

Miller: So you're worried about the friction as it goes around the corners?

Dinkel: You're gonna have a lot of that, yeah. So size in this case does matter.

Loveall: Skipping subjects on you, did you watch them lubricate that wire? They stand at the bottom and feed it in and they put wire pulling lubricant on it. Well, the first thirty feet of that conduit is really well lubricated but the last hundred feet doesn't have a drop on it. If that had a way to dispense lubricant as it went through the pipe-

Dinkel: Oh like a sponge-

Loveall: Or if it hit a hundred pounds and then it started squirting out lubricant.

Dinkel: Sometimes we do try to lubricate ahead of time. If it's going to be a difficult run, they'll run a rag with the lubricant through it and try to get it lubricated ahead of time.

Loveall: But if I catch them doing that, they're in trouble. They've done soaped the rope, now you're trying to pull a rope that has lubricant on it.

[laughter]

Miller: So if we're looking at this more as a small application, for a hand pull, as opposed to a large pull, do you guys use the cable socks on small cable pulls as well?

Dinkel: No, not really. We could, but a kit we bought, it paid for itself after one pull but it only goes down to a conduit size of 2". That's the smallest it goes. Typically we don't do anything above 6" conduit, but anything below 2" not very often do we use the cable socks.

Miller: Okay. So below 2" you're doing the wrapping and making the pulling head, doing the 15 minute process we seen?

Loveall: Mm-hm. Bigger wire, we use an application like this (directed towards an image of a Greenlee Tugger). It pulls 10,000 pounds, two speed motor, you don't want to get into that.

Miller: Okay, so is this something that you guys would be interested in changing for the small pulls? Do you do enough small pulls that you're looking for a solution?

Dinkel: All the time. Every day, we do a small pull.

Miller: What percentage of your pulls do you think are small pulls?

Loveall: Around 70%. You gotta remember, every outlet, every recepticle, every light, we can do by hand but all HVAC equipment, if we gotta go up to the roof... around 90% of our conduit is $\frac{1}{2}$ ", $\frac{3}{4}$ ", and 1". Small conduit and small wire.

Miller: So currently do you guys always make the head like we saw, or do you ever push the cable through?

Loveall: It's really hard to push flexible cable through conduit. You can do it for runs less than 10 feet but nothing really longer than that.

Dinkel: If I had to guess, if I was gonna use this for the smaller wires, instead of even twisting it on, because they have the tendency on the outer jackets to really not hold up too well to the tension, I would maybe do a quick loop on this (referencing the steel braided cable) to snag the cables.

Loveall: That's the biggest thing. If it works and saves him that \$5, that's great. If it fails and now I've got five guys pulling it all back out, laying the cable on the ground, re-tooling it all, tying it back on to go back, we've lost several hundred dollars. So yeah, it's gotta work. Test it, test it, test it. And maybe even coordinate with a wire manufacturer.

Mansard: Is this tapered?

Miller: Yessir, it's an internal taper that grips tighter the more you twist it on.

Dinkel: 3D Printed?

[some jokes about getting a 3D printer for the office and making bobblehead figurines]

Dinkel: I think you're onto something here, Tyler. You've got some room for improvement - there's obviously a lot of competition out there. This isn't the first time it's been thought of, but you gotta keep it simple and stupid.

Miller: Okay so if I were to go back, make some changes and come back what would you like to see changed about this design? It'll be made of metal, what else?

Loveall: Durability. Prove to me it's gonna last. Price wise you're probably gonna be in the \$200-\$300 mark per set. If I'm gonna lay that money out, it's gotta work and it's gotta work repeatedly. I want to be a one-time customer. I want to buy it off you and I want to use it until it absolutely, positively wears out. Now, I might buy multiple sets for all my jobs, but I want to know it lasts. That's what we've gotta have. Now, the good thing for you is that my guys will lose them. They'll throw 'em on the ground, kick 'em, lose 'em, and I'll come back and buy another set from you because they work. They'll lost 'em in the dirt, in the mud, outside on the light-pole bases, they'll be gone.

Dinkel: Now, the funny part is that these cost you about \$0.50 to make and you can sell this for \$50 and sell a hell of a lot more of them at \$50 and you could at \$300.

Loveall: I don't know. It's one of them things that if you price it too cheap, it's like those pocket knives you gave me. You know, if it's too cheap then there's no engineering behind it, there's no design, they just winged this out and you know how it is. You want to get value for your money.

Dinkel: Well, you sell this one at \$50 and you sell the self-lubricating one at \$300.

Loveall: Of course, we get a free one.

Dinkel: We get all free sets because we need to actually test it. We have to.

Miller: Of course. I'd expect that, if you guys are testing it for me, you'd keep the set.

Dinkel: Well we want fifty of them, for everyone.

[laughter]

Miller: Oh, I don't know about that.

Loveall: (to Dinkel) And put 'em on eBay, right?

Miller: So how about this, after break, if I come back with a full set that I show can hold up to 250 or 300 pounds, and I show that I can repeatedly use it, and the cables are fine, would you be willing to try it in the field for me?

Dinkel: Absolutely. We'll give it a whirl. See if you can exceed 300 pounds. That's the big question. Chris, would you say that we need to possibly exceed 300 pounds?

Loveall: If you get 1 ½" and 2", yes. It would exceed 300 pounds.

Dinkel: We're talking about a thousand pounds would be a good place to be, if you could get to there. That's the goal to achieve, and I'd love to see something like you're saying, self-lubricating. Like, a sponge of some sort. You're not going to get all of the bells and whistles but something of that sort.

Loveall: And if you bring it back to us, give us a little time because there's different jobs, you know, and we've got another job starting. It's all conduit right now, we won't be pulling wire there for three months. But we've got different places, we can set something up. We can make it work. We'll get it tested out.

Miller: Okay, excellent.

Loveall: But even if it don't work, don't ever quit, man. There's always a niche.

Dinkel: This is fantastic that you've got to this point.

Loveall: How many did Edison have up before he finally found one?

[some laughter, then some more discussion about a self-lubricating grip]

Miller: Do you usually lubricate hand-pulls?

Loveall: If we ever foresee difficulty, we'll lubricate. Sometimes we don't because the bucket is all the way on the other side of the job site and I don't want to get my hands greasy. But we don't want some guy yanking his guts out trying to get cable through conduit. It's supposed to be done intelligently and smoothly. But if you've been out there for a while, you know we've got both kinds of electricians out there.

Dinkel: (referencing the demonstration conduit) Where did you get this from?

Miller: I got that from Menards.

Loveall: If you ever need stuff like that, come see me. I've got a warehouse full of crap. Sycamore does.

Dinkel: Yes, we've got plenty. So if you need some studying, feel free to come on over.

[some discussion follows about the mechanical division of Sycamore Engineering]

Dinkel: Well, if you have any other questions for us, give us a call. And let us know when you come up with your next big thing and when you've got this ready, as well. And tell your buddies to come on down.

Loveall: Electricians, unlike pipefitters and plumbers, will always entertain new ideas, new gadgets, new tools, and new things. We always like that stuff.

Miller: Well, thank you very much guys. I'll stay in touch with you and I'll get a hold of you if I need anything else.

Dinkel: No, thank you.

Loveall: Like I said, if you got any questions or anything like that, or if you want to see another pull done, absolutely.

Appendix E: Matlab Code

```

clear all
close all
clc

%static variables
conduitNominalDiameter = [0.500 0.750 1.000 1.250 1.500 2.000 2.500 3.000
3.500 4.000 5.000 6.000]; %inches
conduitInternalDiameter = [0.622 0.824 1.049 1.380 1.610 2.067 2.469
3.068]; %inches
conduitBendRadius = [4.250 4.500 5.750 7.250 8.250 9.500 10.50
13.00]; %inches
gripTaper = [9 9 9 9 9 9 9 9]; %degrees
wireGauge = ['4awg' '3awg' '2awg' '1awg' '1/0' '2/0' '3/0'
'4/0'];
wireDiam = [0.2040 0.2290 0.2580 0.2890 0.325 0.365 0.410
0.460];

%Manipulatable Variables
factorOfSafety = 7; %percent
minWallThickness = 0.07; %inches
widthBoringBar = 4/32; %inches
DSel = [0.00 0.00 0.95 1.22 1.41 1.92 2.25 2.80]; %the selected Diameter
(in) of grip for each conduit size
HSel = [0.00 0.00 1.90 2.70 3.20 3.25 4.20 5.10]; %the selected Height (in)
of grip for each conduit size

for n = 1:length(DSel)-3
    %90 Degree Bend Length Limit
    w = 0:(1/16):3.5;
    L = (1 -
factorOfSafety/100).^2.*sqrt((conduitBendRadius(n)+conduitInternalDiameter(n)
/2)^2-(conduitBendRadius(n)-conduitInternalDiameter(n)/2 + w).^2);
    figure(n)
    plot(w,L,'LineStyle','-', 'color', [0 0 1], 'LineWidth', 2);
    hold on
    set(gcf, 'Position',[250 250 750 250]);

    %Min Diameter
    plot(w, (w - widthBoringBar -
2.*minWallThickness)/(2.*tand(gripTaper(n))), 'LineStyle', '-.', 'color', [0
1 0], 'LineWidth', 2);

    %Min Machinable Length
    plot(w, w/2, 'LineStyle', '--', 'color', [1 0 0], 'LineWidth', 2);

    %Min Ergonomic Length
    plot(w, w./w.*1.650, 'LineStyle', ':', 'color', [0 0 0], 'LineWidth', 2);

    %Selected Point
    plot(DSel(n), HSel(n), 'm*');

    %Label Graph

```

```
    xlabel('Grip Exterior Diameter (inches)')
    ylabel('Grip Exterior Length (inches)')
    str = sprintf('Design Space | %2.2f-inch Conduit',
conduitNominalDiameter(n));
    title(str)
    xlim([0 w(end)]);
    ylim([0 L(1)*2/3]);
    grid on
    grid minor
    %set(gcf, 'position',[750.*mod(n-1,2) 200 800 500]);
    legend('90deg Bend Limit','Min. Diameter','Min. Machinable Length', 'Min.
Ergonomic Length', 'Selected Point');
end
```

Appendix F: Cost Analysis of Manufacturing

Material Costs

Costs of material are expected to be less than the information provided in the following table. This table was formed using retail prices from McMaster Carr's online catalog, and thus does not reflect the discounts associated with purchasing materials in large quantities. Five grips are assumed to be included in each kit, along with five (and an extra) anchored cables, one (and an extra) connecting link, and one repair screwdriver.

Table 14: Material Costs of Aluminum Stock (prices and SKUs from mcmaster.com)

Material	SKU	Diameter	QTY	Cost	QTY Required per Kit	Cost per Kit
6061 Aluminum Rod	8974K28	1 ½"	72"	\$64.45	3.20"	\$2.86
6061 Aluminum Rod	8974K11	1 ¼"	72"	\$50.18	2.70"	\$1.88
6061 Aluminum Rod	8974K13	1"	72"	\$35.46	1.90"	\$0.94
6061 Aluminum Rod	8974K16	¾"	72"	\$21.13	1.25" (approx.)	\$0.37
6061 Aluminum Rod	8974K28	½"	72"	\$14.00	0.75" (approx.)	\$0.15
Sum:						\$6.20

Table 15: Material Costs of Kit Accessories (prices and SKUs from mcmaster.com)

Material	SKU	Size	QTY	Cost	QTY Required per Kit	Cost per Kit
Flexible Wire Rope	3450T24	1/16"	any	\$0.27 / ft	*6 x 8"	\$0.90
Wire Rope Stop	3914T11	1/16"	50	\$7.81	*6	\$0.78
Oval-Shaped Threaded Connecting Link	8947T14	3/8"	1	\$1.02	*2	\$2.04
Miniature Screwdriver	7026A25	0.125"	1	\$4.95	1	\$4.95
Plastic Housing	-	-	1	\$6.00	1	\$6.00
Sum:						\$14.67

**note that an extra component has been included in each kit*

It should be pointed out that the plastic housing is priced at-cost for the material used if 3D printing the part. This price will vary depending on the method used for manufacturing the housing, whether it be injection molding, form pressing, or purchasing an existing container as an off-the-shelf solution.

Labor Costs

It was discovered during the manufacturing process that the time required to machine each grip varies only slightly with the size of the grip being created; therefore all sizes of grips may be assumed to have equal manufacturing times. Manufacturing time varies depending on the machinery used, the skill of the technician, and the condition of the tooling.

At first, the author was able to manufacture one grip approximately every four hours. The learning curve associated with the manufacturing process is steep, and by the sixth or seventh grip the author was able to manufacture a grip every once every hour. The time to manufacture a grip is expected to be shortened further by the introduction of CNC machinery as well as introducing a batch process, manufacturing many grips in bulk. Since the most time-consuming step in manufacturing is cutting the threads, the time to manufacture grips is expected to be shortened to approximately 10 minutes per grip with the aid of automated CNC machines.

The internally anchored component is fabricated in two steps: cutting the wire to length and crimping on the wire stop. There was little learning curve associated with the task, and each internal anchor can be manufactured by hand with approximately 1 minute of labor.

The average rate charged for machining on lathes and/or mills is approximately \$120 per hour, as estimated by professional machinists². Furthermore, the average rate for general labor not involving machines is \$50 per hour³.

Component	Labor	QTY	Total Labor	Labor Rate	Cost per Kit
Aluminum Grip	10 min	5	50 min	\$120/hr	\$100
Internal Anchor	1 min	*6	6 min	\$50/hr	\$5
Sum:					\$105

**note that an extra component has been included in each kit*

Other Costs

Since the kits are assumed to be manufactured in machine shops owned by partners of the company, the cost of tooling and utilities are not taken into account. Rather, it is assumed that the tooling cost is distributed among the per-hour rate to manufacture the grips, especially because the 6061 aluminum may be machined using low-cost high speed steel (HSS) tooling.

The costs of advertisement are not considered as the costs vary greatly depending on the medium of content delivery. That is to say, the prices between online advertisement and marketing through trade magazines differ greatly and have not been investigated deeply enough to determine the type of advertising desired nor the effectiveness in reaching customers. However, when determined, the costs of advertising shall be distributed among the costs on a per-kit basis.

² On Reddit's r/machinists page, a page for machinists around the globe to meet and discuss their practice, a question was posed about the average charge for per-hour of machining. The charges range from \$80/hr on low end work to \$200/hr on 5 axis mills, with an average of approximately \$120/hr. https://www.reddit.com/r/Machinists/comments/3uliw0/what_do_your_companies_charge_customers_per_hour/

³ The same machinists also disclosed their rates for general labor not involving machines, which is approximately \$50 per hour.

Final Cost Estimate

Summing the costs of labor and materials yields a total per-kit cost of \$125.87, which is approximately half of the expected price per kit. This number may fluctuate depending on the discounts seen when purchasing materials in large quantities, as well as the labor costs associated with manufacturing the product.

However, the number seems to be somewhat accurate; a request for quote (RFQ) was sent to D&D Automation Inc. in Terre Haute, IN and a quote was given at “around \$41 or less per grip, depending on the difficulty of the cut.” This would result in a total of \$205 in labor per kit, however this RFQ was for a batch of 10 grips, and the per-unit price is expected to fall to levels predicted in the previous tables when larger quantities of grips are requested. A similar quote was given by Checkered Past Racing Products, who quoted the grips at \$35 per part, or \$175 in total labor, with the addition of \$20.87 in material costs, for a total cost of \$195.87 per kit.

Appendix G: Proprietary Documents and NDAs

Non-Disclosure Agreement

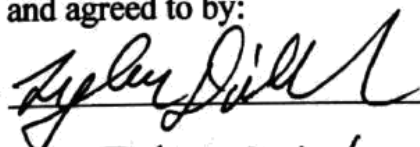
I agree that any information disclosed to me by the Inventor in connection with the Invention will be considered proprietary and confidential, including all such information relating to the Inventor's past, present, or future business activities, research, product design or development, personnel, and business opportunities.

Confidential information shall not include information previously known to me, the general public, or previously recognized as standard practice in the field.

I agree that until the sooner of A) a period of two years or B) public disclosure of the Invention, I will hold all confidential and proprietary information in confidence and will not use such information except as may be authorized by the Inventor and will prevent its unauthorized dissemination. I acknowledge that unauthorized disclosure could cause irreparable harm and significant injury to the Inventor. I agree that upon request, I will return all written or descriptive matter, including any physical representation of the Invention, and supporting documents to the Inventor.

Accepted and agreed to by:

Signature



Printed Name

Tyler Pinkel

Inventor

Tyler Miller RHIT student



Date

12/22/17

Non-Disclosure Agreement

I agree that any information disclosed to me by the Inventor in connection with the Invention will be considered proprietary and confidential, including all such information relating to the Inventor's past, present, or future business activities, research, product design or development, personnel, and business opportunities.

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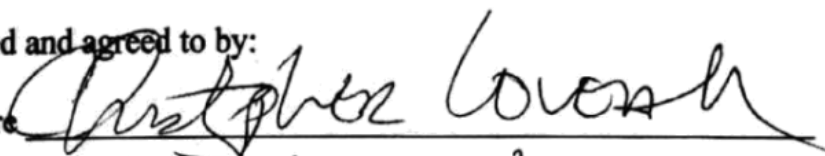
Accepted and agreed to by:

Signature

Printed Name

Inventor

Date



Christopher Lovan



12/22/2017

Non-Disclosure Agreement

I agree that any information disclosed to me by the Inventor in connection with the Invention will be considered proprietary and confidential, including all such information relating to the Inventor's past, present, or future business activities, research, product design or development, personnel, and business opportunities.

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Accepted and agreed to by:

Signature

Printed Name

Inventor

Date

12/23/17
correction: 12/22/17